

# MAMMALIAN ANATOMY

A PREPARATION FOR  
HUMAN AND COMPARATIVE ANATOMY

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# PREFACE

SOME years ago a course of instruction in Mammalian Anatomy was devised and conducted at the University of Pennsylvania by the present writer, in the belief that a careful and exhaustive study of the structure of an inferior animal would be an excellent preparation for the study of human anatomy and would form a foundation broad enough for more extended work in morphology.

The animal selected as best fulfilling all requisites was the cat, which in certain anatomical regards approaches more nearly to man than the dog; it is not specialized for any one mode of life, like the rabbit, and is of convenient size and easily obtained.

The interest and progress of the students and the effect upon their subsequent studies early demonstrated the value of this course. Great difficulty, however, was encountered in teaching accuracy and the observation of detail, and much time was lost through the repetition of lectures and demonstrations, owing to the fact that none of the existing text-books sufficiently covered the ground, or emphasized the close relationship between the anatomy of the inferior animal and the anatomy of man.

It was to supply this need that these pages were begun; and as they continued it seemed possible that, if what was at first a mere outline should be enlarged into a text-book, the study of anatomy might be more generally encouraged and disseminated through our higher schools and colleges, and a student, even a very young student, boy or girl, working alone, perhaps at home, might be enabled to master unaided essential facts without laboratory facilities and remote from the repulsiveness of the dissecting-room. This volume is the result, and the first of a series which aims to present a more accurate and more comprehensive description of the structure of a typical mammal than has been hitherto attempted. This treatise may be therefore regarded as a monograph on a typical mammal, and be em-

ployed as an introduction to general comparative anatomy; and inasmuch as in its general scope, in its methods of description, in the prominence given to practical detail and comparison, and as far as possible in its terminology, it is in accord with the standard textbooks on human anatomy, it may be confidently used in preparation for the study of human anatomy, especially by those who propose to enter a medical course.

Unquestionably the only true way to study human anatomy is to dissect the human subject. It is also unquestionable that this study will be more effective, and time and valuable material saved, if the student bring to the task a familiarity with methods and a knowledge of details acquired in the dissection of an animal belonging to the Mammalia, man's own class, and especially of one whereof the anatomy agrees to such an extent with man's that the few differences either are unimportant or when marked may furnish a key to more complicated human structures. It is not unlikely, moreover, that there is many a one who, while desiring a general knowledge of human anatomy, is yet unable to attend a medical school. To such a student this volume is offered in the assurance that the careful dissection of a typical mammal will be of more service than the reading of books and the examination of models. The conviction that study to be worthy of the name must be thorough is the justification for what may seem an exaggerated elaboration in the descriptions in the following pages.

The present volume deals with the skeleton of the cat, and is complete in itself. An introductory chapter treats of the structure and classification of bones, their parts and features, and the practical methods of study, with an explanation of the general terms used in description. This introduction is followed by a systematic study of every bone and of the regions which they form when joined together. The description of a bone includes an explanation of its name, the areas for muscular attachment, its articulations, rules for rapid identification, the centres of ossification from which it is developed, its growth, and its variations. The corresponding bone in the human skeleton is then carefully compared with it. Under the explanation of the name of a bone are given the Latin or Greek original terms, together with the English derivatives and the corresponding terms in French and German. The meaning and derivation of all special technical terms are given in foot-notes.

A PREPARATION FOR

# HUMAN AND COMPARATIVE ANATOMY

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THE ASSOCIATION OF AMERICAN ANATOMISTS, ETC.

## PART I.

ITS MUSCULAR ATTACHMENTS, GROWTH, AND VARIATIONS

COMPARED WITH

THE SKELETON OF MAN

*WITH OVER FIVE HUNDRED ORIGINAL ILLUSTRATIONS, AND MANY TABLES*

PHILADELPHIA

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Although many of the reforms proposed in anatomical nomenclature are truly admirable, yet, not having been generally adopted, their employment in this work would, it is to be feared, cause confusion, and lessen its value as an introduction to human anatomy.

An experience of ten years with anatomical and biological classes has led to the conviction that the processes of development can be best understood after the adult structure is thoroughly mastered. Then, and not until then, can the study of embryology, with the aid of the microscope, abundant embryological material, and appropriate methods, be successfully pursued. It is proposed, therefore, to consider embryology together with histology in a succeeding volume of the series.

The illustrations of human osteology have been taken from other treatises; all the illustrations of the bones of the cat have been drawn and engraved expressly for this work. Unless otherwise noted, these drawings represent the objects enlarged to twice the natural size. To save time, the same figure is occasionally repeated.

Although errors must lurk in a work embracing so many details, all the statements have been made from personal observation and many of them repeatedly verified.

I am indebted to Mr. Joseph McCreery for the skill and vigilance with which he has read the proofs of these pages, and for many criticisms and hints of which I have gladly availed myself.

The remaining volumes of the series are in preparation, and will be issued as rapidly as possible.

HORACE JAYNE.

THE WISTAR INSTITUTE,  
February, 1898.





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# MAMMALIAN ANATOMY

## THE SKELETON OF THE CAT

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### CHAPTER I

#### INTRODUCTORY

**Mammalian Anatomy**<sup>1</sup> treats of the structure of those vertebrate animals known as Mammals. It is a part of **Biology**,<sup>2</sup> the science of living things, and of its subdivision **Morphology**,<sup>3</sup> the science of form.

As all living things are either plants or animals, the study of plants being termed Botany, the study of animals being termed Zoology,<sup>4</sup> Morphology is divided into **Vegetal Morphology** and **Animal Morphology**.

Animal Morphology is subdivided into several sciences.

It may treat of the general structure of the animal body, of its parts and organs, and of their form, size, character, and relation. This is known as **Descriptive Anatomy**.

It may treat of definite regions of the body, describing all structures found therein and their relations to one another. This is known as **Regional or Topographical Anatomy**.

It may treat of the gradual development of animals before birth. This is known as **Embryology**;<sup>5</sup> and when it deals with the development of an individual animal, it is termed **Ontogeny**.<sup>6</sup> The history

<sup>1</sup> From (Gr.) *anatemnein*, to cut up.

<sup>2</sup> From (Gr.) *bios*, life, and *logos*, discourse.

<sup>3</sup> From (Gr.) *morphè*, form, and *logos*.

<sup>4</sup> From (Gr.) *zoon*, an animal, and *logos*.

<sup>5</sup> From (Gr.) *embryon*, embryo, and *logos*.

<sup>6</sup> From (Gr.) *on*, the individual, and *genos*, race.

of development by **descent** through a line of other animals is termed **Phylogeny**.<sup>1</sup>

When the anatomy of different animals is studied and their homologous organs are compared, this study is known as **Comparative Anatomy**.

The classification of animals into larger and smaller groups is studied under a subdivision of Morphology termed **Taxonomy**.<sup>2</sup>

The consideration of their life in the past, as shown from fossil remains, constitutes the science of **Palæontology**.<sup>3</sup>

**Physiology**,<sup>4</sup> in contrast to Morphology, which treats of the structure of living things, is the science which treats of the workings of these structures, or their functions. For example, under Morphology we study the structure of the lungs and their development, and under Physiology we study the processes of breathing or respiration.

Descriptive Mammalian Anatomy may be divided into two parts :

The first part comprises the study of the microscopic structure of tissues and of organs which constitute the body. This part is **General Anatomy**, or **Microscopic Anatomy**, or **Histology**.<sup>5</sup>

The second part is **Macroscopic**, or **Special Anatomy**, and comprises the study of structures visible to the naked eye.

Histology is studied by means of the microscope; Special Anatomy is studied by dissection, which is the cutting apart and disentangling of the various structures. The study of animals by dissection is sometimes called **Zootomy**.<sup>6</sup>

The most direct way of acquiring a knowledge of mammalian morphology is by a thorough study of the anatomy of one mammal; the facts thereby gained show the general plan of structure, and will serve as a basis for comparison with other animals.

In our selection of the mammal as the subject of study we are much restricted; the requirements are exacting. It must be a familiar animal, and readily obtained; of convenient size, not too large to handle easily, nor too small to make dissection difficult; it must offer

<sup>1</sup> From (Gr.) *phylon*, stem, and *genos*.

<sup>2</sup> From (Gr.) *taxis*, orderly arrangement, and *nemein*, to distribute.

<sup>3</sup> From (Gr.) *palaaios*, ancient, *onta*, beings, and *logos*.

<sup>4</sup> From (Gr.) *physis*, life, and *logos*.

<sup>5</sup> From (Gr.) *histos*, a tissue, and *logos*.

<sup>6</sup> From (Gr.) *zoon*, an animal, and *temnein*, to cut.



as far as possible an average development in all its parts, and it must not be subject to great variations in structure.

The animal which best fulfils these conditions has been found to be the Cat. The dog varies so much in size and structure that uniformity is difficult to secure; the rat is too small, and shares with the rabbit a disadvantage in belonging to the rodents, a specialized group of mammals; the horse, cow, and sheep are inconveniently large, and are also adapted to special modes of life. Even the human body, in the dissection whereof countless comparative anatomists have received their first training, cannot be selected as representing a typical mammalian form because of the changes due to the assumption of an upright posture, and by reason of the reduction of some structures, and of the increased complexity of the brain and many of the bones of the skull.

#### GENERAL STRUCTURE OF THE CAT.

The cat is a vertebrate; it possesses the leading vertebrate character,—namely, an internal skeleton, whereof the axis is the skull and the jointed vertebral column, enclosing respectively the brain and the spinal cord. It is, moreover, a mammal; the females suckle their young by means of mammary glands.

Its body is composed of **organs** grouped into **systems** according to the history of their development and according to the nature of the work to be performed. These Systems are:

1. The **Skeletal**, comprising organs of **support** and passive organs of motion;
2. The **Muscular**, comprising the active organs of motion;
3. The **Alimentary**, comprising organs of **digestion**, for the reception and adaptation of food, and the closely related organs of **respiration**, for the supply of oxygen and the excretion of carbon dioxide;
4. The **Uro-Genital**, composed of organs of **excretion**, for the elimination of waste nitrogenous material, and of organs of **reproduction**, for the propagation of the species;
5. The **Vascular**, embracing organs of **circulation**, for supplying to the tissues, by means of the blood, oxygen and food, and for removing to excretory organs the waste products;
6. The **Nervous**, comprising organs for receiving impressions of different kinds; for producing and carrying nervous impulses; and for **regulating** the activity of organs of the other systems;

7. The **Tegumentary**, comprising the **skin** and its appendages, for protection and excretion; and the organs of the **special senses**,—feeling, seeing, hearing, smelling, and tasting,—developed from it.

The organs composing these systems are made up of **tissues**, whereof the ultimate microscopic elements are the **cells** and the **intercellular substance**, or **matrix**, whereby they are held together.

There are five Tissues in the body:

1. The **Corpuscular**, comprising the **blood** and **lymph**, with rounded cells or corpuscles in a fluid matrix;

2. The **Connective** or supporting tissues, forming **bones** and **cartilage** and **fibrous** connections of all kinds;

3. The **Epithelial**,<sup>1</sup> limiting external and internal surfaces;

4. The **Muscular**, forming most of the **flesh** or **muscles**, and contracting to produce motion;

5. The **Nervous**, comprising nerve-cells and nerve-fibres, for the generation and transmission of nervous impulses.

The organs of the body are composed of these different tissues in varying proportions; for example: bone is composed almost exclusively of a special kind of connective tissue having a hard matrix; the muscles are largely muscular tissue bound together by fibrous tissue, and penetrated by blood-vessels and nerves; blood-vessels are tubes of fibrous connective tissue, muscular tissue, and epithelial tissue; and the skin contains epithelial tissue, connective tissue, muscular tissue, nervous tissue, and corpuscular tissue.

An examination of tissues shows that their differences lie chiefly in the form of the cells, in the character of the intercellular substance, and in the relations which exist between these cells and the intercellular substance. Between these tissues there is another difference, and an extremely important one (not revealed by any microscope), which is manifested by the functions of the tissues, or, in other words, by the nature of the work which they perform. To understand these differences in function we must understand the qualities or nature of the single cell or egg from which the entire body is developed, or the nature of a cell which remains functionally at the same stage of development as the egg. Within the body such cells are the white corpuscles of the blood; outside of the body, as independent animals, they are called *amœbæ*. When a white blood-corpuscle, or an *amœba*,

<sup>1</sup> From (Gr.) *epi*, upon, and *thelê*, a nipple, a papilla.

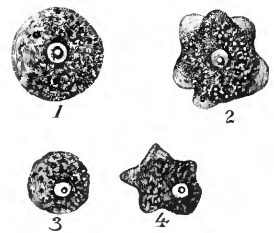
divides, it produces other cells in all respects similar to the original cell; in the egg, however, repeated subdivision or **segmentation** forms cells whereof some change into one kind of tissue and some into another. The products of division of the amœba therefore are said to remain **undifferentiated**; the products of segmentation of the egg are said to **differentiate**, that is, to assume various forms and functions.

The functions apparently assumed by cells produced by segmentation of the egg are not new developments, but are inherent in the original egg as qualities of every living organized cell, serving to distinguish it from a particle of dead, unorganized matter. If we examine under the microscope an amœba, we observe (*a*) that it is a globular mass which has the power of movement, and (*b*) that some of the movements are the result of external stimulation, and hence that it may possibly possess **sensation** and **volition**, or will-power. Moreover, an amœba will enclose within its own body adjacent particles of food, and, by changing them chemically, make them part of its own substance, and will reject whatsoever material it does not need. Hence we conclude that an amœba has the additional functions of (*c*) **absorption**, (*d*) **assimilation**, and (*e*) **excretion**. We are able to note further that to maintain life it needs a constant supply of oxygen from the air; hence we infer that it has the added function of (*f*) **breathing**; and, finally, we see it divide into two cells, thus exhibiting the function of (*g*) **reproduction**.

If we make a chemical analysis of the substance whereof the amœba is composed, we recognize it as **protoplasm**, the principal constituent of every living cell, and a compound of carbon, oxygen, nitrogen, and hydrogen.

The round of life with an amœba is, that under the influence of oxygen its protoplasm is oxidized, or burned, with the consequent production of heat and of energy of some kind (for example, movement), and with the excretion of carbon dioxide and waste nitrogenous matter. It repairs the loss of its protoplasm by taking to itself fresh carbon, oxygen, nitrogen, and hydrogen from its food, casting out the resultant

FIG. 1.



THE ORGANIC CELL.

1, 2, a parasitic amœba of the cockroach, magnified 160 diameters. 1, in the quiescent state; 2, in movement. 3, 4, a colorless blood-corpuscle, 800 diameters. 3, quiescent; 4, in movement.

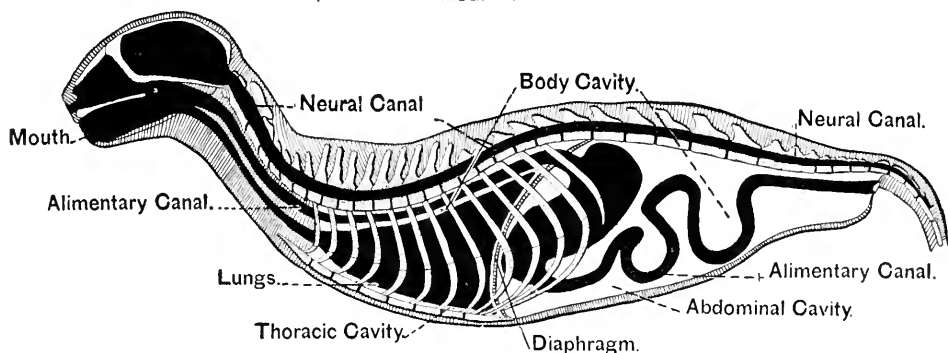
waste products. Under certain conditions it divides to produce two independent cells.

Such are the general qualities of the original animal cell, but only some of them are retained by the cells produced by segmentation. For example, in those cells which are differentiated into cells of muscular tissue contractility is supreme, and other functions are subordinate or disappear; in the cells of the nervous tissue the generation of nervous impulse and the reception of sensation are supreme, but contractility is lost. In other cells, such as gland-cells, food is worked over and products are thrown out, as milk, saliva, or sweat. The red corpuscles of the blood become oxygen-carriers for the other tissues. In many of the connective tissues—for example, bone—the cell is subordinate to its derivative, the intercellular substance; in some epithelial tissues there is but little intercellular substance, and the cells closely united take on the functions of a membrane.

#### PLAN OF THE BODY.

The cat's body is constructed on the general mammalian plan. It consists of a head and trunk supported by four limbs. A plane passing through the long axis divides the body into right and left halves, and, as one half is, in the main, similar to the other half, the body is said

FIG. 2.



PLAN OF VERTEBRATE BODY.

to be bilaterally symmetrical. The end which terminates in the head differs from the end which terminates in the tail. There are traces of original construction which render possible a division of the body into transverse segments, or *metameres*. Examples of these traces are the segmentation of the vertebral column of the skeleton into vertebrae;

the origin of the spinal nerves from the spinal cord in series; the arrangement of muscles; and the resemblance between the anterior and the posterior limbs.

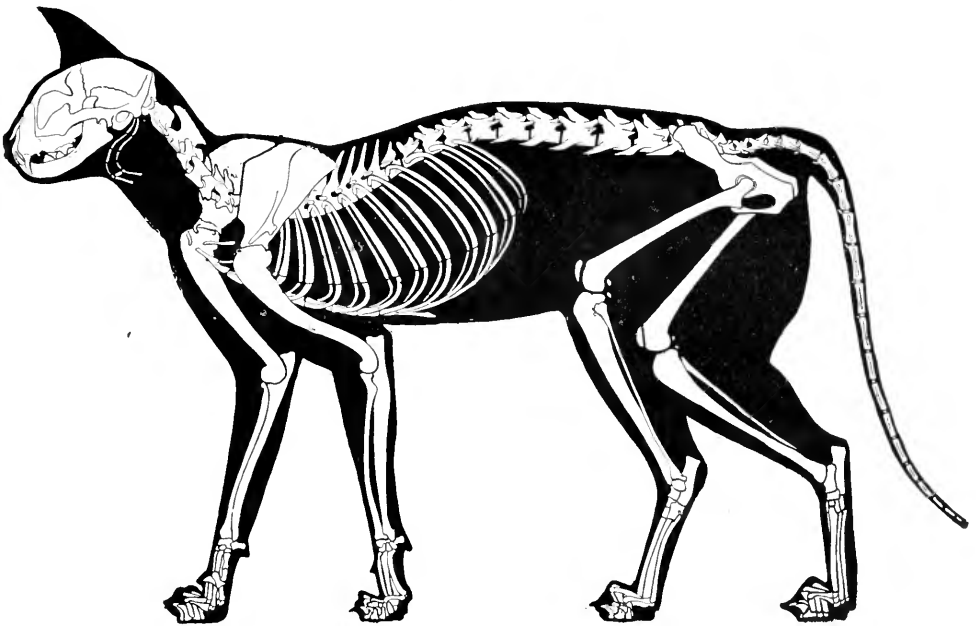
The body of a vertebrate may be said to be made up of two longitudinal tubes.

On the dorsal side of the body, in the skull and spinal column, is a long tube, the **neural canal**, for the brain and spinal cord; on the ventral side is a larger tube surrounded partly by bone, partly by muscles, and known as the **body cavity**. This ventral cavity contains the alimentary canal and its appendages, the lungs, the heart and great blood-vessels, and the central organs of the uro-genital system. It is divided transversely by a muscular partition into two parts, whereof the cavity near the head is the **thoracic cavity**, containing the thoracic viscera, chiefly the heart and lungs, and the cavity near the tail is the **abdominal cavity**, containing the abdominal viscera, which comprise most of the alimentary and uro-genital systems.

#### THE SKELETON.

The **skeleton** in a comprehensive sense consists of the bones, the cartilages, with the ligaments that bind them together, and all that fibrous framework which surrounds and penetrates the organs

FIG. 3.



THE SKELETON OF THE CAT.

and forms a support for the softer parts. So essential is the skeleton that if it were possible to remove the softer non-skeletal parts, no change in the form or size of the body would be perceptible.

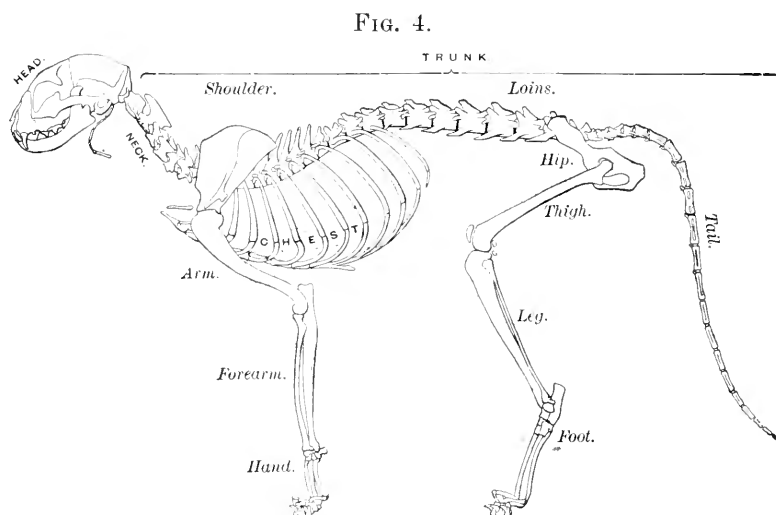
The term skeleton,<sup>1</sup> in this sense, is rarely used; it often refers merely to the bones, cartilages, and ligaments,—the fibrous framework of the body being regarded as part of the various organs. It is usually further restricted to the bones and the few cartilages found connected with them after the processes of maceration, cleaning, and drying. It is in this last sense that it is used in the present volume.

#### PARTS OF THE SKELETON.

The bony skeleton is divided into the **Axial Skeleton** and the **Appendicular Skeleton**.

The **axial** skeleton comprises the one hundred and thirty-six bones of the **head** and **trunk**.

The **appendicular** skeleton comprises the one hundred and sixty-four bones of the two pairs of **limbs**.



THE REGIONS OF THE SKELETON.

The bones of the axial skeleton are distributed throughout the different regions as follows:

In the **head**, forty-three bones.

In the **vertebral column**, fifty-nine bones.

In the **chest**, thirty-four bones.

<sup>1</sup> (Gr.) a dried body.

The bones of the vertebral column are seven in the **neck**, thirteen in the **thoracic** or chest region, seven in the **loins**, three in the **pelvis**, and twenty-nine in the **tail**, whereof eight, however, are the inconspicuous **chevron**<sup>1</sup> bones.

The bones of the appendicular skeleton are distributed as follows :

In each of the **thoracic** limbs or **arms**,—

Two **shoulder** bones.

One **arm** bone.

Two **forearm** bones.

Thirty-seven **hand** bones.

In each of the **pelvic** limbs or **legs**,—

One **hip** bone.

One **thigh** bone.

Two **leg** bones.

Four **knee-joint** bones.

Thirty-two **foot** bones.

In the appendicular skeleton, eleven bones of each hand, three of each set of knee-joint bones, and eight bones of each foot are very small **sesamoid**<sup>2</sup> bones,—in all, forty-four inconspicuous bones. The sixty pairs of bones which remain after deducting these forty-four inconspicuous bones are those usually described as forming the skeleton of the limbs.

Having thus far acquired a general view of the plan of the cat's body, it behooves the student to supply himself with a skeleton which shall serve as the basis of his work, and without which it will be impossible for him to understand the bones, their names, parts, structures, and uses.

#### METHOD OF PREPARATION.

The work laid out in this volume can be done with one strong knife. It can be done more conveniently, however, if the student have at hand the instruments supplied in a small dissecting case: several dissecting knives, called scalpels, two pairs of forceps, two pairs of scissors, a probe, and a grooved director. Chain-hooks are serviceable, but are not absolutely necessary.

Of the scalpels, one should be of medium size and one small. The rough work of cleaning bones can be done with an old penknife.

There may be one pair of small forceps and another larger, but not

<sup>1</sup> A V-shaped ornament.

<sup>2</sup> From (Gr.) *sesamon*, a seed, and *eides*, like.

too heavy; a stiff spring will tire the fingers needlessly. Both pairs should have teeth on the inside of the tips.

The scissors should be of two sizes, and their blades should be straight. A convenient tool is a small hand-saw, known in trade as a jeweller's saw. It consists of a handle attached to a bow of iron on which is strung a fine saw such as is used for fret-sawing. The best saws for cutting bone are those employed for sawing metal.

A small pair of bone-nippers and several of the dental tools called excavators will be useful for following canals in bone.

A pocket lens is requisite for the examination of small structures.

**Killing an Animal.**—The most satisfactory method of killing a small animal for study is by the use of chloroform. It is rapid, absolutely painless, and cleanly.

The animal is placed in a tight box or a large jar which can be covered closely by a lid; a piece of sponge or a rag wet with three or four teaspoonfuls of chloroform is placed therein, and the lid held firmly for a few minutes while the animal is passing through the stage of intoxication. At the end of twenty minutes, or, at most, half an hour, the animal will be dead. If the box be large or not very tight, more chloroform and a longer time will be required. Before removing it from the box a cloth wet with a few teaspoonfuls of benzine should be slipped in and left for ten minutes, to kill any fleas that may be on the animal. Ether may be used in place of chloroform. It is just as efficient, but produces some discomfort to the animal and acts more slowly.

In the absence of chloroform or ether, the animal may be enclosed in a coarse bag and drowned. A disadvantage of this method, which is probably almost painless, is the inconvenience of the wet fur.

After the animal is dead it should be skinned at once, before the still fluid blood coagulates.

**The skinning** can be rapidly done as follows:

The animal is placed on its back on a piece of board or an old table, and the four legs are stretched out at right angles to the body, and held in that position by cords tied round the paws and fastened to nails in the board or passed under the table and tied together. The fur is then parted, with a comb, down the entire middle line of the body. An incision through the skin is made on this line just behind the point of the chin. A grooved director is now introduced into



the incision and pushed toward the tail along the line indicated by the parted fur, the point of the director running close under the skin and the groove on the shaft lying next the skin.

The skin can be rapidly divided by introducing the point of a scalpel into the original cut and pushing it along the director, the back of the point of course running in the groove in the director. The process is repeated until the root of the tail is reached. Similar divisions should be now made from the middle line of the body down the legs.

When beginning to remove the skin, the student should lift up with the forceps (held in the left hand) one of the corners formed at the intersection of two cuts, and, with the scalpel held as a pen in the right hand, divide the white, loose tissue or **superficial fascia** lying in the angle between the skin and the muscles. After the skin is loosened sufficiently the forceps may be put aside, and for the rest of the process the skin may be held between the thumb and fingers of the left hand. The nearer the cuts are to the under surface of the skin, the cleaner the skin will be when removed, but the greater will be the risk of cutting through it. The nearer the cuts are to the underlying muscles, the more loose fascia will be left on the skin and the greater will be the risk of cutting into the muscles. To skin rapidly, the superficial fascia must be kept tight, so that it shall always form a sheet stretching from the under surface of the skin to the upper surface of the muscles. This can be accomplished by holding it fixed with the ring finger and little finger of the right hand while cutting with the thumb and the other two fingers, or the chain-hooks may be used to hold it tense.

In removing the skin preparatory to cleaning the skeleton it matters little, of course, whether or not the skin be clean or to what extent the muscles are cut; but if the skinning be done with care, experience and skill will be gained for use when careful work is demanded. While skinning, the student should note the difference in the thickness of the skin in different parts of the body, and that it is in some places loosely attached and in other places bound down firmly to the underlying structures. He may also recognize the presence of yellow fat, of blood-vessels and nerves, and of nodular masses, which are glands of various kinds.

**Cleaning the Bones.**—It is first necessary to remove the viscera contained within the abdominal and thoracic cavities. This can be

quickly done by a longitudinal incision into the abdominal cavity through the ventral wall. The glistening membrane, the **mesentery**, which fastens the organs to the walls of the cavity should be cut and the intestine divided as far down in the pelvis as possible. In order to prevent the escape of the contents of the alimentary canal when thus divided, the intestine should be tied in two places close together and cut between the ligatures. The muscular **diaphragm** which separates the abdominal and thoracic cavities should be now cut loose from its attachment to the ribs, and the contents of the thoracic cavity cut and torn free from its walls. Finally, if the windpipe and the œsophagus are divided at the root of the neck, all the viscera can be now removed through the original incision in the abdominal wall.

As much of the muscular tissue should be cut away as is possible without injuring the bones. In this process the arms come off easily; the legs may be removed at the hip-joints. The skull and tail should be removed from the spinal column. Before the vertebræ are separated they should be strung on a stout wire passed through the spinal canal, that their relative order may be preserved. The ribs of one side should be wired together in their proper sequence. When all this has been done, the roughly cleaned bones may be further prepared in one of two ways, by maceration or by boiling.

**Maceration.**—The bones are placed in plenty of clean water in a glass or earthenware jar, and the flesh is allowed to decompose. The water is renewed from time to time, and after a few weeks the bones can be taken out, thoroughly brushed to free them from adhering cartilages and ligaments, and laid out in the air to dry.

**Boiling.**—This is a much more satisfactory way of cleaning bones, and one which can be carried to completion in a few hours, especially if the Soap Solution recommended by Wilder and Gage<sup>1</sup> be used. This solution is composed of water (preferably distilled), 2000 cubic centimetres; strong ammonia, 150 cubic centimetres; potassium nitrate (saltpetre), 12 grammes; hard soap, 75 grammes. The solution is not used at first in its full strength, but diluted; to one part of the solution four parts of water are added.

The bones are put in enough of this mixture to cover them completely. They are then boiled for half an hour, when the solution is

<sup>1</sup> Anatomical Technology as applied to the Domestic Cat, 3d edition, 1892, p. 106.

poured off, and a new supply, prepared in the same way, is substituted. After boiling again for half an hour, the bones are cooled in water and the muscles are picked off. If there be any difficulty in removing the soft parts, the bones should be boiled again for a short time, and then brushed clean with a stiff brush. Finally, when perfectly clean, to remove grease, they are boiled for half an hour in a mixture of equal parts of the pure Soap Solution and water, after which they are washed in clean water and laid out to dry.

It must be remembered that if the skeleton of a kitten is to be prepared, the boiling must be done carefully, or all the epiphyses of the bones will become loose. If, on the other hand, the bones of the skull of an old animal are to be separated, the boiling must be carried still further.

To make the bones still whiter by removing every trace of grease, they may be soaked for several weeks in ether or benzine. Avoid danger from fire.

It will be useful to have for comparison a second skeleton whereof the bones are articulated in their proper position. This skeleton may be purchased from a dealer in natural history supplies, or the student may prepare what is known as a **natural skeleton**, one in which the bones are held together by their natural ligaments. To make such a skeleton the student proceeds as before, except that the skull, ribs, tail, and posterior limbs are not separated from the vertebral column and the boiling in soap solution is carried only far enough to permit of the removal of the muscles. The ligaments which bind the bones together are carefully preserved, and the whole skeleton is arranged on a wire support, in a natural position (Fig. 3), and permitted to dry. The anterior limbs, which are attached to the trunk by muscles only, must be cleaned separately and afterwards secured in place by wires.

The student should also, for the sake of comparison, have access to a human skeleton.

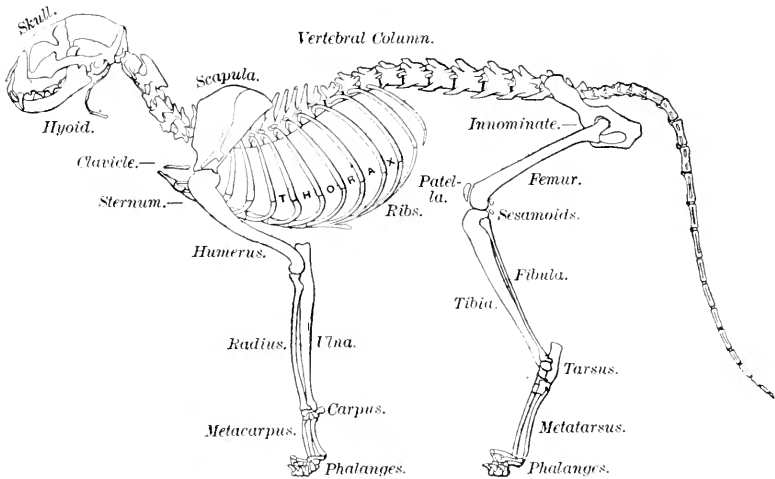
#### NUMBER OF BONES IN THE SKELETON.

The **number** of bones in the skeleton depends upon the **age** of the animal. In a young specimen the number of distinct osseous pieces is much greater than in the adult; the epiphyses are not yet united to the diaphyses, and bones, which in the adult are the result of the

union of several elements, are still separable into their constituent parts. In the adult, on the other hand, all the different parts of the bones have united, and, in a few regions, contiguous bones have coalesced into one mass. This process of coalescence between normally distinct bones may be carried still further in old age.

If the soft parts be carefully removed from an adult skeleton, we find three hundred and twenty-six separable bones. Of these, thirty

FIG. 5.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

are teeth, which are not regarded as parts of the skeleton, and fifty-eight others are inconspicuous and by some anatomists not included in the enumeration; these are the six ossicles of the ear, forty-four small bones, called sesamoids, which are connected with the tendons of muscles, principally those of the hands and feet, and eight chevron bones, attached to the ventral side of the bones of the tail. The two hundred and thirty-eight bones which remain may be increased to two hundred and forty-two, if the two maxillo-turbinals of the skull, always considered distinct bones, be detached from the maxillaries, and if the three elements of the backbone which together form the sacrum be broken apart. Thus the total number of bones, exclusive of the teeth, may be placed at three hundred, although the number will vary slightly, owing to variations in the length of the tail. The majority of the bones, two hundred and twenty-six, are found in pairs, and but seventy-four are single and lie in the middle line of the body.

## BONES OF THE SKELETON.

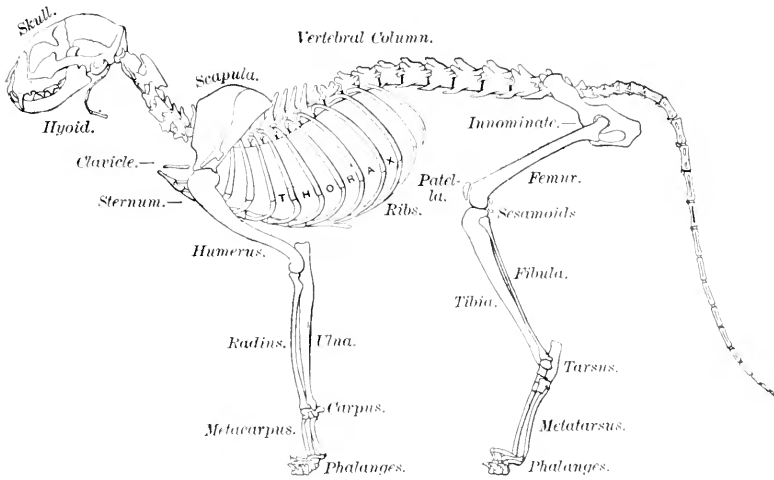
The following is a list of all the bones of the skeleton, with the parts of the body in which they are found. The bones printed in bold-faced type are single bones; all others are in pairs. The numbers in parentheses represent the number of bones of that kind. Where bones are in pairs the numbers should be, of course, doubled to give the total number; for example, "Ribs (13)" means thirteen ribs on each side, twenty-six in all; but "**Cervical vertebræ (7)**" (bold-faced type) means that there are only seven in all.

## AXIAL SKELETON.

Head . . . . .	{	Skull . . . . .	{	Occipital.
				Parietal.
				Interparietal.
				<b>Sphenoid.</b>
				Temporal.
				Frontal.
				<b>Ethmoid.</b>
				Ear ossicles (3).
			{	<b>Vomer.</b>
				Palatine.
				Maxillary.
				Maxillo-turbinal.
				Premaxillary.
				Nasal.
				Lachrymal.
				Malar.
				<b>Mandible.</b>
				<b>Tympano-hyal.</b>
				Stylo-hyal.
				Epi-hyal.
				Cerato-hyal.
				<b>Basi-hyal.</b>
				<b>Thyro-hyal.</b>
Trunk . . . . .	{	Vertebral column . . .	{	<b>Cervical vertebræ (7).</b>
				<b>Thoracic vertebræ (13).</b>
				<b>Lumbar vertebræ (7).</b>
				<b>Sacral vertebræ (3)—The Sacrum.</b>
				<b>Caudal vertebræ (21).</b>
				<b>Chevron Bones (8).</b>
			{	Ribs (13).
				<b>Sternum</b> , composed of <b>Sternebræ (8).</b>



FIG. 5.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

## THE HUMAN SKELETON.

The skeleton of man (Fig. 6) closely resembles that of the cat; it is composed in general of the same bones, bearing the same names and exhibiting the same features; it varies slightly in the relative proportions of its parts and in some minor details of structure. The number of bones is smaller, which, as we shall see, is chiefly due to the larger number of sesamoid bones in the cat.

The most striking difference between the two skeletons is due to the upright posture of man's body, and is associated with shortening of the trunk, flattening of the thorax, broadening of the false pelvis, straightening of the leg, and flattening of the foot. The arm is no longer used in walking, and has gained a firm union to the trunk by the articulation of the clavicle with the sternum. It has, therefore, a wider range of function, with freer motion. The bones of the forearm are capable of more complete rotation, permitting the hand to turn palm forward; and the movements of the thumb have become more complex. A noteworthy difference lies in the form of the skull: the increased development of man's brain has led to the subordination of the face to the cranium, to such an extent that the cranium has assumed the shape of a globe, from the lower anterior part whereof the face is suspended.

The adult human skeleton consists of two hundred and fourteen bones, whereof eighty are in the axial skeleton and one hundred and thirty-four in the appendicular. Some anatomists compute a greater

number by enumerating parts of bones as distinct elements. We have seen that the skeleton of the cat comprises three hundred bones, or

FIG. 6.



THE HUMAN SKELETON.

two hundred and ninety-eight if the sacrum be counted as one piece: hence the cat's skeleton is formed of eighty-four bones more than the human skeleton. This difference is due to the fact that the human skeleton has ten bones not present in the cat, while the cat has ninety-four bones not normally present in man.

The additional ten human bones are: a scaphoid (distinct from the lunar) in each carpus and two phalanges and two sesamoids in each great toe.

Some of the ninety-four bones present in the cat's skeleton, but absent in the human skeleton, are true additional bones; others result from the less extensive coalescence of parts of bones.

The human head has fourteen bones less than the cat's head; the frontals unite to form one bone, the interparietal is absent, the premaxillaries coalesce with the maxillaries, and the eleven elements of the hyoid apparatus are represented by one hyoid bone.

The human trunk has forty bones less than the trunk of the cat, because

there are but twenty-six vertebral elements in place of forty-nine, twenty-four ribs in place of twenty-six, the eight chevron bones are wanting, and the eight sternobræ are represented by a single bone,—the sternum.

The human appendicular skeleton lacks forty sesamoid bones present in the limbs of the cat,—namely, nine in each hand, three behind each knee-joint, and eight in each foot.



## NAMES OF BONES.

The names of the bones given on pages 15 and 16 are the **English technical** names which are generally accepted. There is, however, for almost every bone an additional **Latin** or **Greek** name, whereby the bone can be recognized by anatomists of all countries. Finally, many bones, particularly the limb bones, have **common** names for general use. Thus a bone may bear three names: for example, there is the English technical name the **clavicle**, the Latin *clavicula*, and the common name the **collar-bone**.

In addition to these, bones may have technical or common names, or both, in the different modern languages, and it is necessary to know these names if the student is to read foreign anatomical works. For example, the fibula in French is *le péroné*; in German, *das Wadenbein*. Unfortunately, there is still another burden added to anatomical study, in the form of **synonyms**, or additional English technical names, additional Latin or Greek names, and additional common names, for the same bone; for example, for the innominate bone, *os innominatum*, *os coxae*, hip-bone, and haunch-bone. Indeed, this multiplication of names would render the study of anatomy well-nigh impossible were it not that many of the different names for the same bone are much alike,—*e. g.*, temporal bone, *os temporale*, *os temporis*, *le temporale*,—all having the same derivation, and were not the synonyms gradually disappearing through disuse.

Many of the **Latin** and **Greek** names of bones are very old, and their derivations cannot be always traced. In many cases the names refer to the **part of the body** in which the bone is found; for example, *femur*, Latin for the thigh. Sometimes the names are based upon a **likeness**, real or fancied, to some common object, as *tibia*, the Latin for flute; or, again, they may describe the **shape**, as *scaphoid*, from a Greek word meaning boat-like; or they may designate the relative **size**, as *magnum*.

Explanations of these names, together with some of the Latin and Greek synonyms and the French and German names, are given whenever possible after the description of the bone.

**English technical names**, as a rule, are anglicized Latin or Greek names; for example, lachrymal bone, from Latin *os lachrymale*. In many cases the English technical name is identical with the Latin name; for example, *omer*, *radius*, *fibula*. For some bones the English

common name is used as a technical name; for example, rib is almost universally used instead of the Latin *costa*.

#### CLASSIFICATION OF BONES.

Bones are often grouped, according to their shape, into four classes: **long bones**, **short bones**, **flat or broad bones**, and **irregular bones**. Although this classification is vague and of little scientific value, there is sufficient difference in the character of the bony structure in the groups to render some such classification convenient, vague though it be.

**Long bones** have one of their diameters conspicuously greater than the others. They possess a central shaft, or diaphysis, and two ends, or epiphyses. The interior of the shaft is a medullary cavity filled with marrow. The long bones are the bones of the limbs, forming levers whereon the muscles act.

**Short bones** have no one diameter greatly exceeding the others. They are not divided into diaphysis and epiphyses, and they have no medullary cavity. Short bones are found in the carpus, the tarsus, and the sternum,—places where strength and elasticity with slight movement are required.

**Flat bones** have one diameter conspicuously less than the others. In structure they consist of two plates of compact bony tissue separated by a thin layer of cancellous tissue. The flat bones form the walls of cavities or furnish large areas for muscular attachment. Such are the bones of the cranial vault, the innominate bones, and the scapulae.

**Irregular bones** are the remaining bones which do not fall naturally in any one of the other classes. Their shape is irregular, and in structure they are like both the short bones and the flat bones. Irregular bones are found in the skull, and as vertebrae in the vertebral column.

#### UNION OF BONES.

The consideration of the manner in which bones are joined together properly belongs to **Syndesmology**, which treats of articulations. In order to understand the bones themselves, however, some general facts concerning their modes of union must be made clear.

Bones are united firmly and immovably, or are movable and capable of different degrees of motion. All varieties of union may be grouped under two heads:

1. Incomplete joints by continuous union, or **Synarthro'ses**.
2. Complete joints by discontinuous union, or **Diarthro'ses**.

In the **Synarthroses**<sup>1</sup> the apposing surfaces of the united bones are firmly bound together throughout their whole extent by an interposed tissue, which, after the removal of all the surrounding muscles and ligaments, must be entirely cut through before the bones can be separated.

In the **Diarthroses**<sup>2</sup> the apposing surfaces of the united bones are free, and are held in contact by an investing capsule of fibrous tissue, the capsular ligament, the division of which, if the muscles and certain accessory ligaments have been removed, permits the separation of the bones.

**Synarthroses**, or incomplete joints, are divided into four classes, namely, the **synchondroses**, the **syndesmoses**, the **sutures**, and the **synsarcoses**. The classification is based upon the nature and the amount of the uniting tissue:

1. In a **Synchondro'sis**<sup>3</sup> the bones are united by a plate of **cartilage**. A union of this kind may be movable; for example, a union

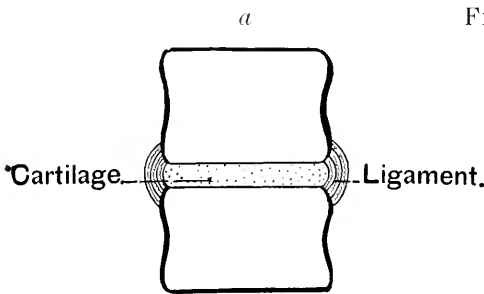


DIAGRAM OF A SYNARTHROSIS.

FIG. 7.

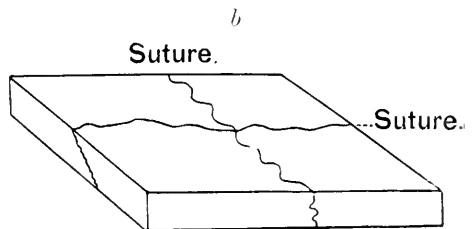


DIAGRAM ILLUSTRATING DENTATE AND SQUAMOUS SUTURES.

of vertebrae by means of cartilaginous **intervertebral disks** (Fig. 7, *a*); or motion may be so far restricted that the bones practically coalesce by **sym'physis**<sup>4</sup>; for example, the two hip-bones are joined by a ventral median symphysis. A similar union, probably without motion, obtains in young, growing bones between the secondary parts, or **epiphyses**, and the principal part, or **diaphysis**; in these cases, however, the

<sup>1</sup> From (Gr.) *syn*, together, and *arthros*, a joint.

<sup>2</sup> From (Gr.) *dia*, between, and *arthros*, a joint.

<sup>3</sup> From (Gr.) *syn*, together, and *chondros*, cartilage.

<sup>4</sup> From (Gr.) *syn*, together, and *phucin*, to grow.

cartilaginous layer is active in the formation of new tissue, while in other synchondroses, so far as known, its function is entirely passive.

2. In a **Syndesmosis**<sup>1</sup> the uniting substance is fibrous tissue. Genuine syndesmoses are relatively infrequent; examples may be seen, however, in the way in which the costal cartilages of the small caudal ribs are united, and in the union of borders of adjacent bones by sheets of **interosseous membrane**.

3. In the **Sutures** whereby the thin bones of the skull are joined together, the uniting tissue, fibrous or cartilaginous, is reduced to such an extent that the edges of the bones appear to be in actual contact and immovable. If the edges of the bones are notched so as to interlock, the union is a **dentate suture**; if the edges are bevelled and overlap, the union is a **squamous suture** (Fig. 7, *b*). Many of the sutures disappear in adult life or old age; they therefore resemble the epiphyseal synchondroses in permitting, for a time, growth of the bones along their edges.

4. In a **Synsarco'sis**<sup>2</sup> the bones are joined by **muscular tissue**. An example of this rare condition is found, in the cat, in the union of the rudimentary clavicle to the sternum and the scapula.

Synchondroses and syndesmoses may be converted into absolutely immovable unions, or **Synosto'ses**,<sup>3</sup> by ossification of the intervening tissue. By the same process the sutures of the skull become obliterated in old age.

**Diarthroses**, or complete joints, are of different forms and the seats of different kinds of motion: some are simple and permit gliding motion; some are hinge-joints with angular motion; others permit rotation; or as ball-and-socket joints have a free motion, known as circumduction.

Whatever be the form or function of a diarthrosis, it possesses certain general characters,—namely:

(a) The apposing surfaces of the united bones are covered with a layer of **articular cartilage** (Fig. 8). This layer of cartilage is rarely of uniform thickness: it may deepen an articular cavity by being thicker round its edge, or it may render an articular elevation more

<sup>1</sup> From (Gr.) *syndesmos*, a ligament; *syn*, together, and *dein*, to bind.

<sup>2</sup> From (Gr.) *syn*, together, and *sarkoun*, to make flesh.

<sup>3</sup> From (Gr.) *syn*, together, and *osteon*, bone.

prominent by being thicker in the middle; thus the articular surfaces on a dried bone, from which the cartilages have been removed, differ in shape and size from the corresponding surfaces on a fresh bone. (b) The uniting **capsular ligament** is a more or less tubular structure fastened by its edges to the bones, often at some little distance from

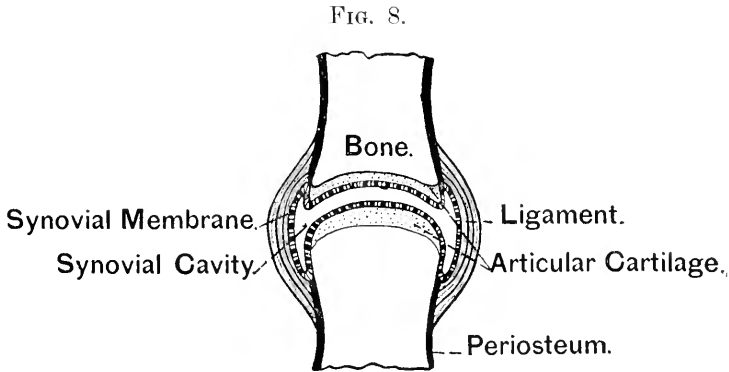


DIAGRAM OF A DIARTHROSIS.

the actual articulating surfaces; it thus encloses (c) the cavity of the joint, which is known as the **syno'vial cavity**, because it is (d) lined by a delicate **synovial membrane** which secretes (e) the **synovia**,<sup>1</sup> the lubricant of the articulating surfaces.

Joints are rendered more complicated when a pad, or several pads, of cartilage are interposed between the articulating surfaces of the bones, or when a ligament within the joint passes from one bone to the other.

#### GENERAL CHARACTERS OF BONES.

**DRIED BONE.**—If the student examine one of the long bones which has been cleaned and dried, the following general characters will be observed:

**Color.**—Normally the color of a dried bone is yellowish white. If, however, it has been exposed for some time to the sun or to certain chemicals, it will be bleached to a bluish white or chalk color, and if, moreover, it has not been thoroughly cleaned, it will be more or less brown. Bones are sometimes accidentally colored during the process of maceration; they turn black if macerated in an oaken vessel in the presence of iron; or red or blue if taken from animals injected

<sup>1</sup> From (Gr.) *syn*, together, and *ovum*, an egg; resembling the white of egg.

with these colors in order to show the course and distribution of the blood-vessels.

**Weight.**—The dried bone is light: its coverings have been stripped off, and the softer part of the bone substance, the marrow, the blood-vessels, and the nerves, which fill its interior, have been removed, and their place is taken by air. The actual weight of bones varies with their size; their relative weight varies with the density, or compactness, of the bone tissue. When the weight of a bone is compared with the weight of an equal volume of distilled water, the result is known as the specific gravity of bone. Hence if the weight of the bone's volume of water be put at 1, the weight of the bone in a fresh state will be found to vary from 1.87 to 1.97.

**Odor.**—A perfectly clean bone should be odorless; usually, however, a faint odor can be detected, due to the chemicals used in cleaning, or to the dried and partially decomposed particles in the medullary cavity, or in the bone substance.

**Hardness.**—With the single exception of the teeth, bone is the hardest substance in the animal body. If the central part of a long bone be cut with a sharp knife, it will be noticed that the hard tissue is thick and dense, but if the end be shaved the hard tissue will soon be cut through and a spongy tissue exposed. Thus there is a difference in hardness in different parts of a bone. There is also a difference in the hardness of different bones.

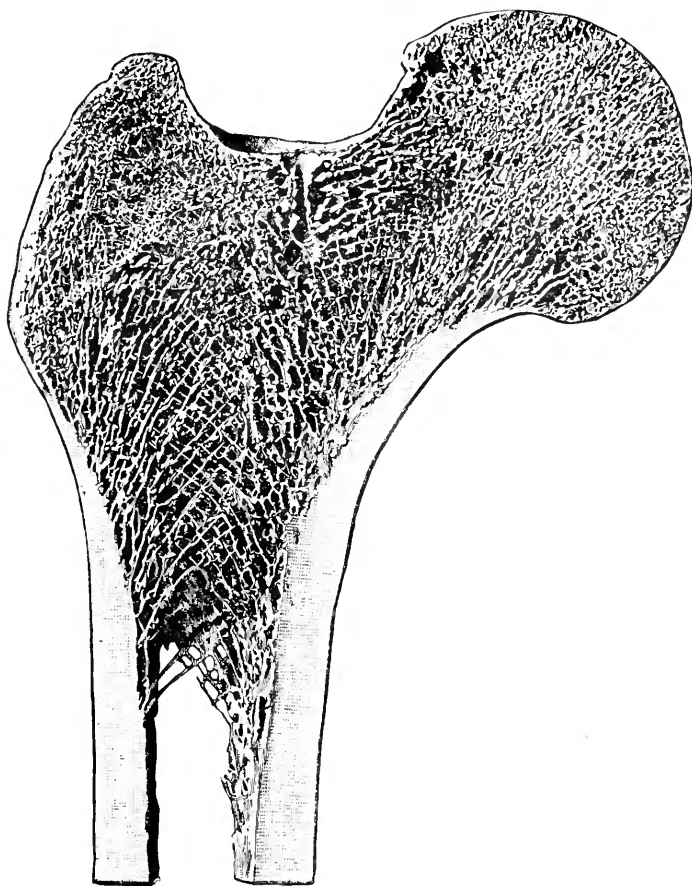
**Strength.**—A dried long bone can be easily broken. This, however, is not a fair test of strength, inasmuch as it has lost many toughening qualities; nor are the living conditions by any means present under experiments to show the weight which a piece of bone, fresh or dried, will support before crushing, or the number of pounds which can be suspended from it before its fibres separate.

**Elasticity.**—It will be noticed that the bone under examination can be bent slightly and when released will assume its original form. If it be dropped end downward on the floor, it will rebound. These facts show that it possesses elasticity, the power of returning after pressure to the original form and size.

**External Appearance.**—If the surface of the bone be now examined more closely, it will be seen to be for the most part smooth and shining and covered by very fine lines and minute holes; nearer the ends, however, it is rougher and more porous. Roughened lines and

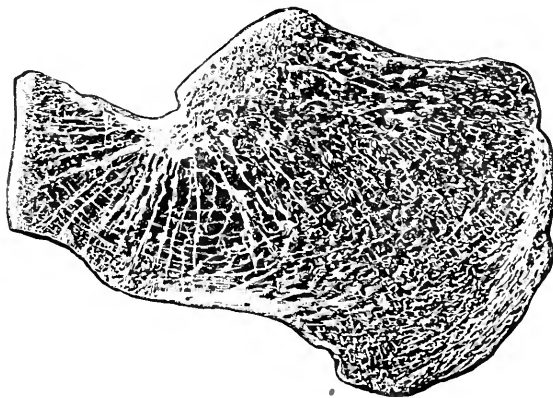
FIG. 9.

*a*



STRUCTURE OF CANCELLOUS TISSUE.

*b*



STRUCTURE OF A SHORT BONE.

projections at various places mark the firm attachments of muscles and ligaments. All openings in the surface have been divided into three grades: first, the microscopically small openings scattered everywhere over the surface and giving entrance to vessels, nerves, and fibres from the periosteum, the investing membrane of the bone; second, larger openings at the ends of bones for larger vessels and nerves; and, third, one still larger opening, situated in the shaft, usually nearer one end than the other, and piercing the compact tissue obliquely. This is the **nutrient foramen**, for the principal artery and its accompanying veins.

**Internal Structure.**—If the bone be sawed lengthwise and the interior exposed, the central part, or shaft, will be seen to be a tube of dense **compact** tissue surrounding the medullary cavity. Near the ends of the bone this compact tissue thins out to a mere crust by giving off internally plates and rods, which crossing and interlacing form the **cancellous** tissue of the ends, with the meshes whereof the medullary cavity of the shaft freely communicates (Fig. 9, *a*). If the bone be a young growing bone, a transverse line of epiphyseal cartilage will be observed separating the shaft from the ends; if the bone be from an older animal, the original position of the cartilage will be indicated by a line of denser tissue.

The interior of a flat bone, such as the scapula, is composed of two layers of compact tissue separated by a layer of cancellous tissue, and in very thin places of a single layer of compact tissue. In the flat bones of the skull the cancellous tissue is known as the **diploë**,<sup>1</sup> and the limiting layers of compact tissues are known as the external and internal **tables**.

One of the short bones should be now examined, and by a cross-section the interior, composed of cancellous tissue limited by an external crust of compact tissue, exposed (Fig. 9, *b*).

**FRESH BONE.**—A bone in the fresh or natural state presents a different appearance from a dried bone, and shows parts which the latter has lost in the processes of cleaning.

If a fresh bone of a cat be not conveniently available, an arm-bone of a sheep, or one of the smaller beef-bones, which can be always obtained in market, will serve equally well. A second bone, split lengthwise by the butcher, will be necessary for the examination of the interior.

<sup>1</sup> From (Gr.) *diploos*, double.



**External Appearance.**—A fresh bone is covered, to a greater or less extent, by red flesh, or muscular tissue, which can be easily torn away in some places and at other points is firmly attached to the bone either directly or by means of a glistening white fibrous band, the **tendon**, or by a fibrous sheet, the **aponeurosis**<sup>1</sup> or **fascia**.

The parts of the surface of the bone to which muscles are attached are called areas of insertion or areas of origin of muscles. A muscle is said to be *inserted* in the bone which is to be moved, and to *arise* from the bone or part of the skeleton which in reference to this one motion is regarded as fixed. The student will observe near the ends of the bone additional bands of tough, yellowish-white, fibrous tissue, which, though closely associated with the muscles, are not their tendons, but serve to bind the bone to an adjacent bone. These are the **ligaments**. To expose the surface of the bone, the muscles and ligaments should now be removed.

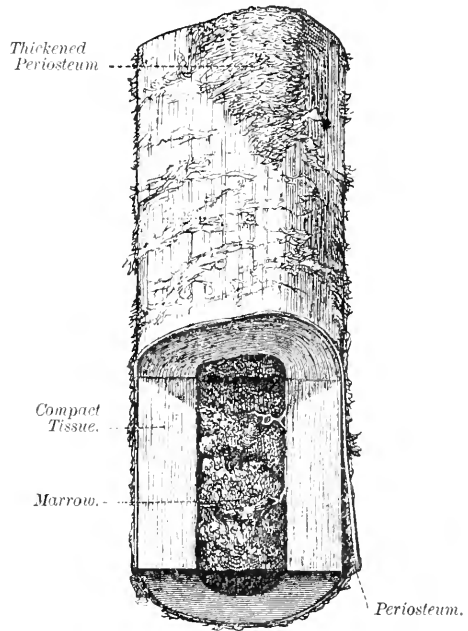
The **color** of a fresh bone differs from the color of a dried bone; it is a light pink, due principally to the color of the blood. The ends, however, are pearl-colored, inasmuch as they are covered with a layer of translucent **articular cartilage**, which can be readily cut with the knife. The rest of the bone is covered with a thin but tough membrane. This membrane is the **perios'teum**,<sup>2</sup> which has three functions: it is the structure by which the muscles are attached to the bone; it contains the blood-vessels for the bone; and, in its lower layer, it produces bone tissue. The loss of the periosteum leads to the death of the underlying bone.

If the periosteum be now stripped off, its delicate thread-like

<sup>1</sup> From (Gr.) *apo*, from, and *neuron*, originally a fibre, then a nerve.

<sup>2</sup> From (Gr.) *peri*, around, and *osteon*, bone.

FIG. 10.



PORTION OF THE SHAFT OF A FRESH BONE.

vessels and fibres will be seen entering the bone. At points where the muscles and ligaments are attached it cannot be easily removed; it is bound closely to the underlying roughened surface.

**Internal Structure.**—The fresh bone appears to be solid because the medullary cavity is filled with marrow. The two kinds of marrow should be observed,—the yellow marrow filling the medullary cavity proper, and the red marrow filling the spongy tissue in the ends of the bone.

#### STRUCTURE OF BONE.

Bone is composed almost entirely of one kind of connective tissue, the **osseous tissue**, which, in common with all tissues, is made up of a matrix and protoplasmic cells. The matrix is impregnated with lime salts, which give hardness and rigidity to the bone. These salts are mainly calcium phosphate and calcium carbonate, and they form two-thirds of the weight of the bone. They may be removed by acids, leaving only the animal matter, or **ossein**, which resembles cartilage in some respects, and forms the other third of the bone's weight. After treatment with acid the bones become pliable, although remaining tough and elastic. The animal matter, on the other hand, can be removed from a bone by burning it; there are then left only the bone salts, which retain the original shape and size of the bone, but are friable and crumble away if handled roughly. When bones are burnt without free access of air, the animal matter is charred, producing animal charcoal.

Bone tissue is traversed by vascular canals, which are small in the denser tissue, but become irregular spaces in the spongy parts.

The protoplasmic bone-cells are of microscopic size and of irregular shape. They communicate by long branches with one another and with the vascular canals, and in this way form a close living network throughout the harder matrix.

The compact tissue is exceedingly dense, and to the naked eye appears to be solid.

The cancellous or spongy tissue exhibits small cavities or spaces which in the recent state are filled with marrow. The bony plates which bound these spaces and form the walls of the meshes do not pass indiscriminately in all directions, but have a definite arrangement, which varies with the nature of the bone and with the purposes for

which it is designed, and resembles the arrangement of beams and trusses used in architectural construction (Fig. 9). A bone is thus enabled to bear all kinds of strains with an economical disposition of its tissue; it supports weight, and resists the traction of muscles. That the structure of bone is largely the result of mechanical forces is shown by the fact that when bone tissue is destroyed it is replaced by new bone whereof the fibres are arranged along the lines of greatest pressure and greatest tension.

**Bone Marrow.**—The marrow of the bone is of two kinds: the yellow marrow, which fills the medullary cavities, and the red marrow, which occupies the spongy substance.

The yellow marrow is almost pure fat; the red marrow, which is red largely because of the presence of blood-vessels, contains more protoplasmic elements and in growing bones is more abundant.

Associated with the marrow and lying close to the bone tissue are peculiar cellular elements which during growth destroy useless bone tissue, and are hence known as **osteoclasts**.<sup>1</sup>

#### PARTS OF BONES. FEATURES ON BONES.

Inasmuch as all bones are irregular, to study them thoroughly it is necessary to resolve them into their various parts, to define their surfaces and their borders, and to describe the elevations and depressions and other features which produce their characteristic irregularity. By **parts** of a bone are meant those larger divisions which, as a rule, at one time were once separate pieces; for example, the head of a bone. The classification may be arbitrary, however, and adopted merely for convenience of description.

In the same manner as a bone itself may have several names, a part of a bone, or a feature on a bone, may have two names: an English technical name and a Latin or a Greek name, as head and *caput*, border and *margo*. Most of the English names are common English words used in their ordinary sense, as border, spine, angle; others are transliterations of Greek terms, as condyle, from the Greek *κόρυμβος*; apophysis, from the Greek *ἀπόφυσις*; and a few, adopted from the Latin into the language without change, are now used only in anatomy, such as *foramen*, *sinus*.

<sup>1</sup> From (Gr.) *osteon*, bone, and *klastos*, broken.

## GENERAL TERMS USED IN DESCRIPTION.

**Aspect.**—When a bone or a combination of bones is viewed from a given direction, the portion seen is called an **aspect** or **view**. Example: lateral aspect of the skull, *norma lateralis cranii*.

**Region** is a name used to denote locality on one bone or on a number of bones. Example: the palatine region of the skull, *regio palatina*.

## PARTS OF BONES.

The **body** (*corpus*) of a bone is its principal part. It is usually the seat of primary ossification; it gives the general shape to the bone, supports the secondary parts, and affords extensive attachments to muscles. Example: body of the scapula, *corpus scapulae*.

**Shaft** is a term used to designate the body or principal portion of a long bone. Example: shaft of the humerus, *corpus humeri*.

**Centrum** is applied to the disk-like or cylindrical body of a vertebra: *centrum vertebrae*.

**Diaphysis** (Greek *dia*, between, and *phuo*, to grow) is another name for body, shaft, or centrum.

**Extremity** is employed to denote the end of a bone, particularly the end of a long bone. Example: upper extremity of the tibia, *extremitas superior tibiae*.

**Epiphysis** (Greek *epi*, upon, and *phuo*, to grow) is another name for end or extremity.

**Mass** is a term used in several cases to denote a large but somewhat indefinite portion of a bone. Example: lateral mass of the sacrum, *massa lateralis*.

A **wing** (*ala*) is an expanded part of a bone. Example: wings of the vomer, *alae vomeris*.

A **plate** (*lamina*) is a broad but comparatively thin layer of bone. Example: orbital plate of the frontal, *lamina orbitalis*.

A **septum** (a wall) is a plate which separates two cavities. Example: nasal septum, *septum narium*.

The **head** (*caput*) of a bone is a rounded prominence at one end for articulation with an adjoining bone. Example: head of the femur, *caput femoris*.

The head is usually separated from the rest of the bone by a constriction known as the **neck** (*collum*). Example: neck of the scapula, *collum scapulae*.

A smaller head is a **capitellum** or **capitulum**. Example: *capitellum humeri*.

**Ramus** (a branch) is a term applied to a division or branch of a bone. Example: ramus of the mandible, *ramus mandibulae*.

**Lingule** or **lingula** (a tongue), **cornu** (a horn), and **ha'mulus** (a hook) are terms employed, in a few cases, for small parts of bones. Examples: lingule of the sphenoid, *lingula sphenoidalis*, cornua of the sacrum, hamulus of the pterygoid.

**Base** and **apex** are terms sometimes used to denote the broad and the pointed end of a bone, respectively. Example: base and apex of the patella, *basis patellae*, *apex patellae*.

**Base** may be applied in the ordinary sense to the lower part of a structure. Example: base of the skull, *basis cranii*.

#### EXTERIOR OF BONES.

The exterior of a bone, or of a part of a bone, presents certain features:

**Surfaces** (*facies*), which may be smooth or irregular; they may afford attachment to muscles or membranes, or may be applied to surfaces of other bones to form joints. Examples: orbital surface of the maxillary, *facies orbitalis maxillaris*; proximal surface of the radius, *facies proximalis radii*.

Parts of surfaces are known as **areas** or **spaces**. Examples: area of origin of the tibialis anticus muscle, popliteal space. Intervals between bones are sometimes termed spaces. Example: intercostal spaces, *spatia intercostalia*. A well-defined space on a bone, either for the attachment of muscles or for articulation with another bone, is sometimes called a **facet**.

The term **border** (*crista*) is used to denote the ridge or convexity produced by the meeting of two surfaces. Example: anterior border of the humerus.

The term **border** (*margo*, *limbus*) is also used in osteology in the ordinary sense, meaning the margin of a thin structure. Example: frontal border of the parietal, *margo frontalis*.

An **arch** is the curved border of an opening. Example: supra-orbital or superciliary arch, *arcus supraorbitalis* or *arcus superciliaris*. Or the term may refer to an actual bony structure arching over a canal. Example: zygomatic arch, *arcus zygomaticus*.

An **angle** is formed by the meeting of surfaces or borders, and may be right, acute, or obtuse. Example: angle of a rib, *angulus costæ*.

In some cases the term **angle** includes also the prominent region of bone around the actual angle. Example: angle of the lower jaw, *angulus mandibulæ*.

Surfaces are marked (1) by **elevations**, (2) by **depressions**, and (3) by **openings**.

(1) **Elevations** assist in articulations and afford greater surface for the attachment of muscles.

In addition to those elevations which were considered of sufficient size to be classified as parts of bones, the names of the following are to be noted:

**Process** is a general term for a projection. If the process bear a smooth articular surface, it is called an **articular** process. Example: articular process of a vertebra, *processus articularis vertebrae*.

**Articular eminence** (*tuber articulare*) is sometimes used for an articular process.

**Apoph'ysis** (Greek *apo*, from, and *phuo*, to grow) is sometimes used in place of the term process.

A pair of rounded articular processes in the same plane are termed **condyles** (knuckles). Example: condyles of the femur.

The meaning of the term condyle has been in several instances extended to include an elevation near an articular swelling. Example: the processes found on each side of the lower extremity of the humerus, or of the femur, known as the internal and external condyles. As they are not true articular swellings, the term epicondyle (Greek *epi*, upon) should be used.

A spool-shaped articular swelling is sometimes termed a **trochlea** (a pulley). Example: trochlea of the humerus, *trochlea humeri*.

A **tuberosity** (*tuber, tuberositas*) is a rough, obtuse, non-articular swelling. It may be clearly defined or may pass down gradually on all sides continuous with the surrounding surface. Example: tuberosity of the calcaneum, *tuber calcaneum*.

**Tubercle** is a term applied to a non-articular swelling smaller and usually sharper than a tuberosity. Example: tubercle of the rib, *tuberculum costæ*.

Tuberosity and tubercle are interchangeable and used by different authors for the same structure.

The tuberosities of the femur are called **trochanters** (Greek *trochein*, to roll), and the tuberosity at the lower end of both the tibia and the fibula is known as a **malleolus** (a little hammer).

**Promontory** in several instances denotes the most prominent part of a surface. Example: promontory of the sacrum, *promontorium sacrum*.

**Protuberance** is occasionally used in place of the term tubercle. Example: external occipital protuberance, *protuberantia occipitalis exterior*.

An **eminence** is an obscurely defined elevation or a point of maximum convexity of a surface. Example: parietal eminence, *eminentia parietalis*.

A long tapering process is called a **spine** or **spinous process** (*processus spinosus*). Examples: post-nasal spine, *spina nasalis posterior*; spinous process of a vertebra, *processus spinosus vertebrae*.

**Crest** is sometimes applied to the border of a bone. Example: crest of the ilium, *crista iliaca*.

**Rostrum** (*beak*) is used, but rarely, for a kind of crest. Example: sphenoidal rostrum, *rostrum sphenoidalis*.

A prominent elevation extending along a surface is called a **ridge** (*crista*). Example: bicipital ridges of the humerus, *cristae tuberculorum*.

A slight elevation along a surface is known as a **line**. Example: *linea aspera* of the femur.

(2) **Depressions** in the surface of bones may be **articular depressions**, to receive articular elevations of various kinds, or may be for the attachments of muscles, or to lodge more delicate structures.

A deep depression is termed a **cavity** (*sinus*); when for articulation, an **articular cavity**. Example: glenoid cavity of the scapula, *cavitas glenoidica scapulae*.

A broad depressed area on a surface is known as a **fossa** (*ditch*). Example: supraspinous fossa of the scapula, *fossa supraspinata*. The depressed area may involve several contiguous bones. Example: temporal fossa, *fossa temporalis*.

A smaller, more clearly defined depression has been termed a **pit**,

or *fovea*, and a faint depression, by some writers, is called an **impression**, *impressio*.

A **groove** (*sulcus*) is a narrow furrow on a bone. Example: bicipital groove on the humerus, *sulcus bicipitalis*.

A deep cut in the border of a bone is termed a **notch** (*incisura*). Example: coracoid notch of the scapula, *incisura coracoidea*.

(3) The exterior of a bone exhibits **openings** leading into the substance of the bone or into cavities of the interior.

The general term for an opening in a bone is **fora'men** (a door). It is used in several ways: for example,—

1. A **foramen** may be an aperture leading into a narrow passage extending through one or more bones. Examples: stylomastoid foramen, *foramen stylomastoideum* of the temporal bone, leading into the facial canal; the nutrient foramina, *foramina nutritia*, of all bones.

2. A **foramen** may be a large opening through one thin bone or between several bones. Examples: *foramen magnum* of the occipital bone; obturator foramen of the innominate, *foramen obturatum*.

The membranous spaces between some of the skull bones at birth are termed **fontanelles** or **fontanels** (*fonticuli*).

3. The meaning of the term **foramen** may be extended to include a short passage-way itself. Example: optic foramen in the sphenoid, *foramen opticum*, which is strictly a passage opening by two foramina.

The term **aperture** is also used for an opening. Example: the nasal aperture, *apertura nasalis*.

A **fissure** is a slit or an elongated opening, usually between two or more bones. Example: sphenoidal fissure, *fissura sphenoidalis*.

The term **hiatus** (from *hiare*, to gape) is used a few times only, to designate an opening into a cavity or a canal. Example: *hiatus Fallopii* in the temporal bone. It has also been used in place of the term **notch**.

#### CAVITIES AND PASSAGES IN BONES.

**Cavity** (*caritas, carum*) is applied to a space in the interior of one bone. Examples: medullary cavity or *carum medullare*, tympanic cavity or *tympanum*. It is also applied to a space enclosed by several bones. Examples: cavity of the mouth, *carum oris*; thoracic cavity, *carum thoracis*. A cavity containing air and having a narrowed outlet is called a **sinus** (a hollow). Example: frontal sinus, *sinus frontalis*.



**Infundib'ulum** (from *infundere*, to pour into) is a term applied in osteology to a funnel-shaped opening from one cavity to another. Example: infundibulum of the frontal sinus.

A **canal** is a passage through one bone or through several bones. Examples: Vidian canal, *canalis pterygoideus*; lachrymal canal, *canalis lachrymalis*. A small canal is a **canaliculus**. Example: tympanic canaliculus. A more conspicuous passage is called a **meatus** (passage). Example: external auditory meatus, *meatus acusticus externus*.

In a few instances a canal is termed an **aqueduct** (from *aqua*, water, and *ductus*, canal), on the supposition that it transmits fluid. Example: cochlear aqueduct, *aqueductus cochleæ*.

#### QUALIFYING TERMS.

It will be noticed that a part of a bone or a feature of a bone has, in addition to its own name,—shaft, canal, tuberosity,—one or more qualifying names which serve to distinguish it from similar parts or features of other bones, and aid in locating it, or even partially describe it; for example, shaft of the **femur**, **Vidian canal**, **greater tuberosity** of the humerus. Of course it would be useless to give a list of all possible qualifying expressions; it will, however, aid the student in remembering these names if they are classified, even if the classification be to a certain extent incomplete.

A part of a bone or a feature of a bone is distinguished,—

1. By the name of the bone on which it is found. Examples: condyles of the **femur**, **parietal eminence**.
2. By its position with reference to the axes of the trunk or the axes of the limb. Examples: **transverse** process of a vertebra; **anterior** surface of the femur; **proximal** end of the tibia.
3. By its position on the bone itself. Example: **supraspinous fossa**, the fossa above the spinous process.
4. By the name of (*a*) a muscle, (*b*) a nerve, (*c*) a blood-vessel, (*d*) some other feature, or (*e*) another bone, related in some way to it. Examples: (*a*) **deltoid ridge**; (*b*) **optic foramen**; (*c*) **jugular notch**; (*d*) **intercondyloid notch**; (*e*) **nasal process**.
5. By its size. Examples: **great trochanter**, **lesser tuberosity**.

6. By its shape.

(a) Through a resemblance, real or fancied, to some common object. Examples: **odontoid** or **tooth-like** process; **cribriform** or **sieve-like** plate; **scaphoid** or **boat-like** fossa.

(b) Through a resemblance to a geometrical figure. Example: **oval** foramen.

7. By a peculiarity of texture. Examples: **petrous** or **rock-like** portion of the temporal bone, **linea aspera**, rough line.

8. By its function, real or fancied. Example: **nutrient** canal.

9. By the name of an anatomist, not necessarily the name of that anatomist who first discovered it. Examples: **hiatus Fallopii** (Fallopian, A.D. 1523–1562), **Glaserian** fissure (Glaser, A.D. 1629–1675).

#### DEVELOPMENT OF BONES.

The greater part of the skeleton is **preformed in cartilage**, in such a manner that every original cartilaginous element has the form of the bone which is to develop in and about it. A few bones, however (almost exclusively bones of the skull), are not first formed in cartilage, but are developed independently in or from membranes. Bones of the first class are said to have an **intracartilaginous** development; those of the second class, an **intramembranous** development.

Ossification is not merely the deposit of lime salts in the cartilaginous or membranous matrix, it is a total transformation of the existing tissues into bone tissue by means of special cells termed **osteoblasts**.<sup>1</sup> It always begins in a **primary centre** which is more or less central, and there may be no other centres. In most bones, however, **secondary centres** (Fig. 12) appear at the ends or in special parts and coalesce with the primary centre, sometimes almost immediately, sometimes not until adult life. As has been already pointed out, the primary centre of long bones is in the **diaphysis**, the secondary centres are in the **epiphyses**.

#### GROWTH OF BONES.

Bones grow by the deposit of new bone material upon that already formed, so-called **appositional** growth, and not by the interposition of new bony molecules between the molecules already present, so-called

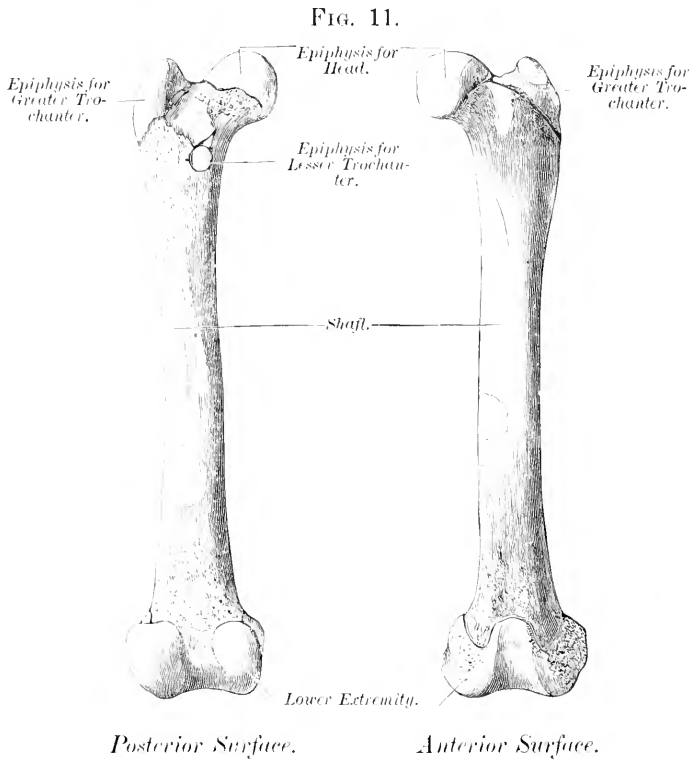
<sup>1</sup> From (Gr.) *osteon*, bone, and *blastos*, a germ.

interstitial growth. Associated with growth is a constant destruction, or absorption, of useless bone structure by osteoclasts.

We may consider briefly growth in length and growth in thickness.

A long bone increases in **length** through growth at each end, where the layer of cartilage separates the diaphysis from the epiphysis.

As the bone develops from a very small primary point near the middle of the diaphysis, the ossification gradually extends toward the secondary points in the epiphyses, and would reach them and coalesce,



PLAN OF THE DEVELOPMENT OF THE FEMUR BY FIVE CENTRES.

were the cartilaginous layers, the remnants of the primitive cartilage, not actively producing on each side new cartilage which the extending centres convert into bone. This activity of the cartilage layers is most marked on the side toward the diaphysis: hence the principal growth in length of a bone is in the shaft. These processes of growth have been demonstrated by a simple experiment. Into a long bone of a young animal two small pegs were inserted at given distances from the middle of the shaft and allowed to remain for some years. The animal was then killed, and examination of the bone revealed that the pegs were still the same distance apart.

A flat bone increases in **diameter** through growth along its edges. An early union of two contiguous bones results in an arrest of growth and a narrowing of the part. This is observable in the human skull, wherein early union of the two frontal bones produces a narrow forehead.

**Growth in thickness** is produced by the **deposition** from the periosteum of new bone on the **external** surface and an **absorption** of old bone from the **internal** surface. Thus the medullary cavity, if present, enlarges by the destruction of its walls. To show this method of growth, a broad ring has been placed around a bone of a living animal; after the lapse of sufficient time the animal was killed, and the ring found within the medullary cavity.

**Absorption of bone.**—It has been noted that most bones are pre-formed in cartilage with the shape which they will have when completely ossified. Since the growth in length takes place at the ends of the bones, we should expect to find the cartilaginous elevations which are near the ends of the bone, but on the diaphysis, gradually assuming a position nearer the middle of the shaft. This is not the case, however; their relative positions are constantly maintained by a growth of the side of the elevation near the epiphysis and an absorption of material from the side of the elevation near the middle of the diaphysis. The elevation therefore might be said to travel slowly but constantly toward the end of the bone until the epiphysis coalesces with the diaphysis.

**Relative Growth.**—It has been observed that the rate of growth is not the same for all bones, and also that the growth of any one bone does not proceed in all parts with the same rapidity. In long bones one end grows faster than another; the primary centre reaches the epiphyseal cartilage and unites with the secondary centres earlier at one end than at the other. We have noted that the nutrient canal of the shaft pierces the compact tissue obliquely, and hence is directed toward one end of the bone; observation of the processes of growth reveals that the end toward which the vessel is directed unites first with the shaft.

#### GENERAL TERMS USED IN OSTEOLOGY.

The terms which are used to show the relations of bones to the exterior, and their relations to one another, are somewhat different when applied to bones (1) of the trunk, (2) of the head, and (3) of the limbs.

(1) The trunk presents **right** and **left** sides; a back, or **dorsal** side; a belly, or **ventral** side; a head or **cephalic** end, and a tail or **caudal** end. The usual position of the vertebrate body is with the belly toward the ground; hence the ventral side is also called the lower or inferior side, the dorsal side is the upper or superior side, the cephalic end is the anterior end, and the caudal end is the posterior end. Moreover, the body as a whole is divided into right and left halves by a median plane.

Bones, like other organs, are situated within the body, and hence, in describing their various sides and their relations to one another and to other organs, terms of direction are usually employed. For example, the side or end of a bone near the head is called the anterior side or end, or, if one bone lies nearer the head end than another bone, it is said to be anterior to it. The upper or superior end of a bone is the end near the upper side or back of the body; one bone nearer the back than another is said to be above or superior to the other. The end or side of a bone near the median plane is called the inner end or side; of two bones the one nearer the median plane is said to lie internal to the other. Moreover, lines drawn at right angles to the median plane are transverse lines; lines in or parallel with the median plane are longitudinal lines, and lines connecting the back and the belly are vertical lines. These terms, which are extrinsic, based upon the animal's posture, would be sufficiently accurate and universal if every animal walked on four limbs, but some animals—among them, of course, man—walk on the posterior limbs only, and have assumed, in place of a horizontal posture, an upright one. Hence the terms we have given do not mean the same things when we speak of the human body; ventral means anterior, the head end is not the anterior end, but the superior end, and the dorsal side is not the superior side, but the posterior side.

We need, therefore, terms which can be applied to any animal without regard to its posture. Such terms are called intrinsic terms; they are based upon the relation of one part of the body to another part.

The head end of a bone, therefore, is intrinsically its **cephalic** end, and one bone lies on the **cephalic** side of another if nearer the head. The tail end of a bone is the **caudal** end. The end near the belly is the **ventral** end (Fig. 12), or one bone, or feature on a bone, is **ventral**

to another. The end near the back is the **dorsal** end, or one bone is **dorsal** to another. Inasmuch as inner and outer may be confused with internal and external, the side of a bone near the median plane is

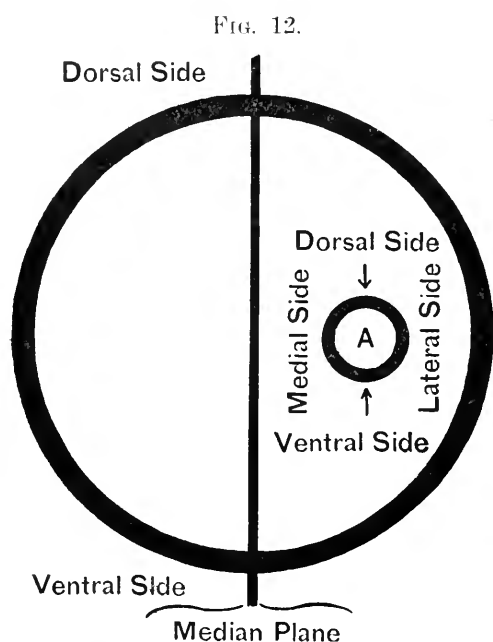


DIAGRAM OF A TRANSVERSE SECTION OF THE BODY, AND OF AN ORGAN, A.

called the **medial** side, and the opposite side is called the **lateral** side. Lines connecting the dorsal and ventral sides are termed **dorso-ventral**, and longitudinal lines are termed **cephalo-caudal**.

The use of intrinsic terms may be still further extended; for example, the end of a rib attached to the vertebral column may be known as the **vertebral** end, and the end near the sternum as the **sternal** end.

Several other terms have been used in place of cephalic and caudal to express the relation of an organ to the head and

tail of an animal: **cranial** and **caudal**, **nasal** and **caudal**, **proserial** and **retroserial**, **oral** and **aboral**.

In describing the bones of the head and of the limbs of a cat, we can use the extrinsic terms used in describing the corresponding human bones; the positions of these parts of the skeleton are practically identical.

(2) The terms cephalic and caudal are awkward in describing the head itself, and no less so the terms dorsal and ventral. The heads of all mammals may be assumed to be held in practically the same position; hence the terms **upper** and **lower**, **anterior** and **posterior**, are sufficient.

For greater exactness it is sometimes desirable to use additional intrinsic terms; as, the **intracranial** surface of a bone, for the surface which shows on the inner surface of the cranial wall; or the **nasal** process of the maxillary bone, in place of the ascending process.

(3) The end of a limb bone near the attachment of the limb to the

body is termed the **proximal end**; the end furthest removed from the attachment of the limb to the body is termed the **distal end**.

The arm and thigh bones have **anterior**, **posterior**, **inner**, and **outer** sides. The outer side of the forearm and hand, however, is termed **radial**; the radius is always situated on that side; and the inner side is termed **ulnar**. The back of the hand is its **dorsum**, or **dorsal side**; the palm is its **palmar side**.

In the hind limb the outer side of the leg bones is termed **fibular**, and the inner side is termed **tibial**. The foot also has a **dorsal side**, and the sole is its **plantar side**. Thus, one of the small bones of the middle of the foot has six sides,—termed proximal, distal, dorsal, plantar, tibial, and fibular, respectively,—and no change in the position of the foot can produce confusion in the description of the individual bone.

In the following descriptions of bones a special endeavor has been made to write plainly and to employ, as far as possible, words in everyday use. For the sake of brevity a few terms common in Descriptive Zoology have been introduced; for example, **sinuate**, like a waving line; **emarginate**, notched or incised, when applied to a border having an incurvature; **arcuate**, arched or bow-like.

The student, having gained a general idea of the skeleton and of the terms used in description, and, moreover, being provided with the bones themselves, needs, before beginning practical study, only a few words, by way of guidance, in the use of this book.

In the first place, although to some Osteology may appear to be an uninteresting study, it should be constantly borne in mind that it is the foundation of anatomy, inasmuch as the skeleton gives general form to the body, serves for the attachment of most of the muscles, and furnishes the fixed points for the other systems. Indeed, most of the names of muscles, blood-vessels, and nerves are derived from the names of related bones. As there is no royal road to learning and no way has been yet discovered by which students can get a permanent knowledge of anatomical facts save by observing them, every point presented in the description must be carefully verified, bone in hand. Little can be gained by merely reading the text and examining the illustrations. The illustrations are introduced simply in order that the student may find at once the feature described, and thus avoid mistakes

and gain time. If the illustrations be studied in place of the specimens themselves, the purpose of this book will be defeated.

The student must not expect to find every bone agreeing exactly with the illustrations of it; all bones vary, some more, some less, and the illustrations have been prepared to exhibit what are believed to be usual conditions. I have called attention to all variations I have seen or have found recorded; the student should remember, however, that the list is by no means complete, and probably never can be completed.

It will be observed that the description of a bone begins with a general statement of its shape, size, and function, its position in the body, and its more evident parts. It is then divided into all its parts, and every part is carefully examined, with all surfaces and borders and peculiar features. Then follow: (1) The explanation of the name. (2) Determination of right and left bones. (3) Articulation with other bones. (4) Muscular attachments. (5) Blood-supply. (6) Method of ossification. (7) Variations in size and form. Unless otherwise stated, every bone is described in its natural position in the body.

Such technical terms as have not been already explained are defined in foot-notes, in popular form, without any attempt at philological nicety. Greek words are printed in italics, preceded or followed by (Gr.).

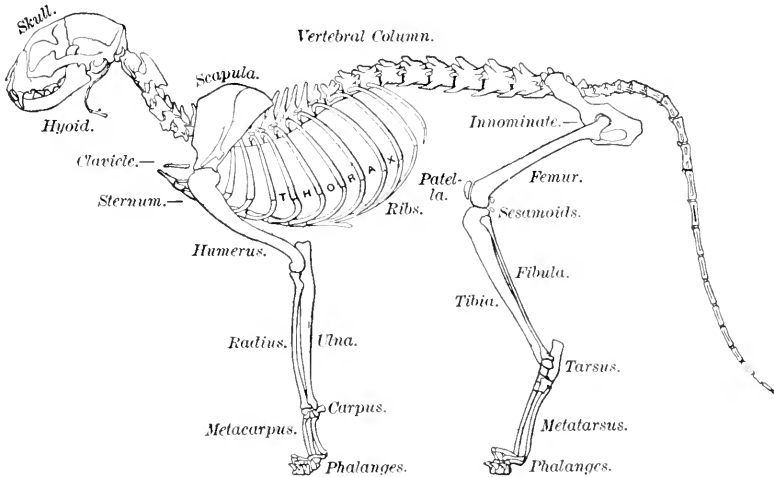
A conclusion may be drawn from the facts presented in this chapter that, in comparison with man's, the cat's skeleton is more elaborate and even more complex. On the principle that the greater includes the less, an exhaustive study of the cat will equip the student with a knowledge of human anatomy which hereafter, however profound may be his researches, will need to be supplemented by differential details only. There can be therefore no more thorough introduction to the study of all anatomy than a complete mastery of the anatomy of the cat.



## CHAPTER II

### THE AXIAL SKELETON—THE VERTEBRAL COLUMN

FIG. 13.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

THE Axial Skeleton is the bony framework of the Head and the Trunk.

In the Head, the axial skeleton comprises:—

1. The **Skull**, which encloses and protects the brain, and forms cavities for the eyes, the ears, the nose, and the mouth;
2. The **Hyoid Bones**, which support the root of the tongue.

In the Trunk, the axial skeleton comprises:—

1. The **Vertebral Column**, or **Spine**, which forms the axis of the neck, the body, and the tail, and dorsally encloses the spinal cord, and ventrally supports the viscera;
2. The **Ribs**;
3. The **Sternum**, or **Breast Bone**.

By the union of the ribs with the sternum and with a portion of the vertebral column is formed the **Thorax**, or bony chest, which surrounds the thoracic and part of the abdominal viscera.

To the axial skeleton is attached, either directly by joints or indirectly by muscles, the appendicular skeleton or framework of the limbs.

The axial skeleton is formed of one hundred and thirty-six bones, divided into :—

The forty-three Bones of the Head :—

Thirty-two in the Skull,

Eleven in the Hyoid Apparatus ;

The ninety-three Bones of the Trunk :—

Fifty-nine in the Vertebral Column,

Twenty-six Ribs,

Eight in the Sternum.

Of the bones of the axial skeleton, seventy-four lie in the median plane of the body, and are single, and bilaterally symmetrical. They are :—

Six Bones of the Skull,

One Hyoid Bone,

The fifty-nine Bones of the Vertebral Column,

The eight Bones of the Sternum.

The remaining sixty-two bones are arranged in thirty-one pairs, distributed as follows :—

Thirteen pairs in the Skull,

Five pairs of Hyoid Bones,

Thirteen pairs of Ribs.

The Bones of the Head should be considered first naturally, but because of their complexity it is customary to begin the systematic study of the Skeleton with the less complex Bones of the Trunk.

#### VERTEBRAL COLUMN.

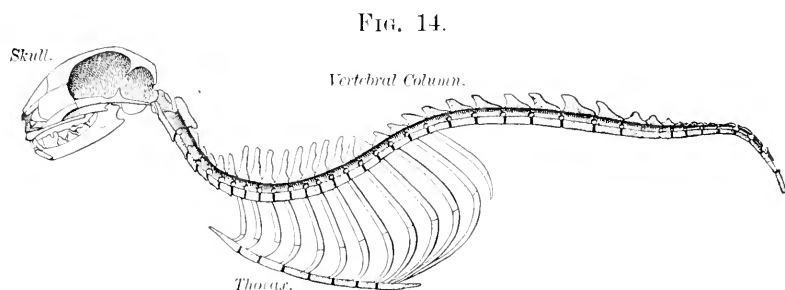
The Vertebral Column may be defined as an irregular bony rod on the dorsal aspect of the body, occupying the middle line. Its cephalic end articulates with the skull, and its caudal end terminates in the tip of the tail. It gives rigidity to the trunk, and is joined through the shoulder and pelvic girdles to the Anterior and Posterior Extremities. By uniting with the ribs it completes the dorsal part of the chest or thorax.

Attached to it are large muscles, which move the head, the trunk, and the extremities, or form the muscular walls of the abdomen.

It is traversed from its cephalic end to the cephalic part of the tail by the vertebral or neural canal, wherein is lodged the spinal cord (Fig. 14).

The column, therefore, is a bony tube with projections for muscular attachment. It is bilaterally symmetrical, but for greater rigidity the ventral wall is thickened into a rod, while the lateral and dorsal walls remain thin.

The vertebral column is not truly a rod, but is broken by joints into a series of small segments arranged end to end. These segments



THE AXIAL SKELETON. LONGITUDINAL SECTION.  
Showing relations of Neural, Oral, and Thoracic Cavities.

are bound closely together, and are more or less movable on one another at the joints. Their close union permits of considerable range of motion to the column as a whole, but guards against disturbance of the spinal cord from extreme motion at any one point.

The segments into which the column is divided are called the **vertebræ**, and, since the column is a tube, each vertebra is a ring or section of a tube. These rings are of varying widths and lengths. They are always bilaterally symmetrical; the ventral part, however, is thickened into a cylindrical mass articulating in front and behind with the adjoining vertebrae. The dorsal part of the ring, in the form of a bony arch, surrounds the neural canal.

In number, the vertebrae vary from forty-eight to fifty-three, according to the length of the tail. They are divided into five groups (Fig. 15), as follows:—

The **Cervical**<sup>1</sup> Vertebrae, the cephalic seven forming the neck ;

The **Thoracic**<sup>2</sup> Vertebrae, the following thirteen, which unite with the ribs to complete the thorax ;

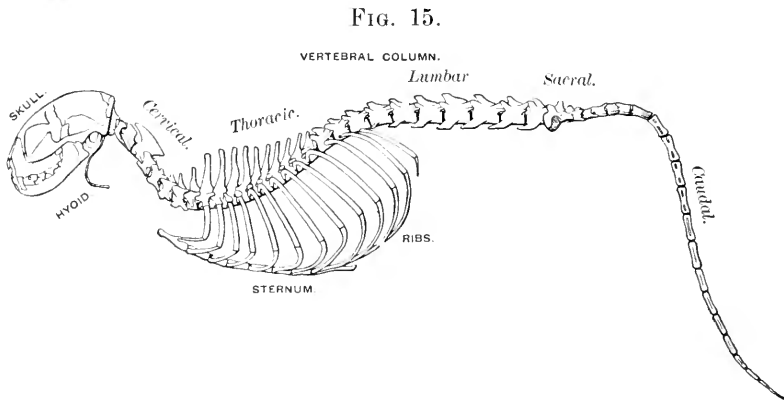
<sup>1</sup> From *cervix*, the neck.

<sup>2</sup> From *thorax* (Gr.), a breastplate ; the breast.

The **Lumbar**<sup>1</sup> **Vertebræ**, the following seven at the dorsal part of the abdominal cavity in the region of the loins ;

The **Sacral**<sup>2</sup> **Vertebræ**, the following three, which are firmly united and form the sacrum, whereto the hip-bones of the hind legs are attached ;

The **Caudal**<sup>3</sup> **Vertebræ**, the remaining eighteen to twenty-three, form the tail.



THE AXIAL SKELETON. (Greatly reduced.)

The Sacral Vertebrae are sometimes called the immovable or **false vertebrae**, as distinguished from the others, the **true vertebrae**.

#### CHARACTERS COMMON TO ALL VERTEBRÆ.

**General Description.**—Each vertebra, whatever its shape, consists of two essential parts (Fig. 16), the ventral cylindrical **body** or **centrum**,<sup>4</sup> and the dorsal transverse **neural**<sup>5</sup> **arch**. The space between the arch and the body is the **neural canal**. The ends of the body are smooth, and bound to the ends of adjoining vertebrae by means of intervening plates of cartilage. The arch is formed of **pedicles**<sup>6</sup> and **laminae**.<sup>7</sup>

The pedicles are the upright ventral parts of the sides of the arch. The laminae slope dorsally and toward each other from the dorsal ends of the pedicles, and, meeting in the middle line, form the horizontal roof of the neural canal; at their point of meeting the vertebra is prolonged dorsally into the **neural spine** or **spinous process**.

<sup>1</sup> From *lumbus*, a loin.

<sup>2</sup> From *sacer*, sacred.

<sup>3</sup> From *cauda*, the tail.

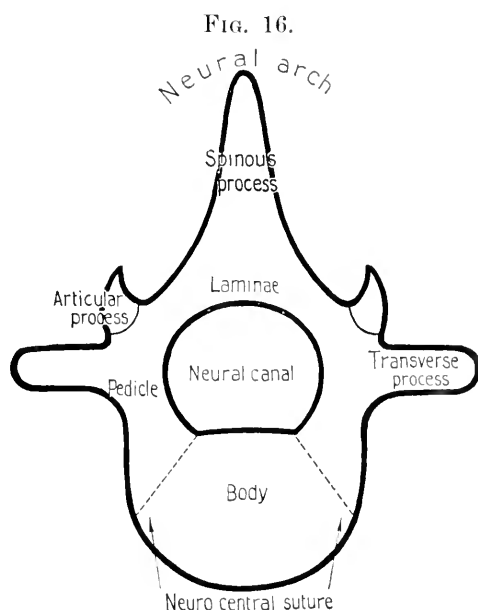
<sup>4</sup> *Centrum*, centre.

<sup>5</sup> From *neuron* (Gr.), a nerve.

<sup>6</sup> From *pediculum*, a little foot.

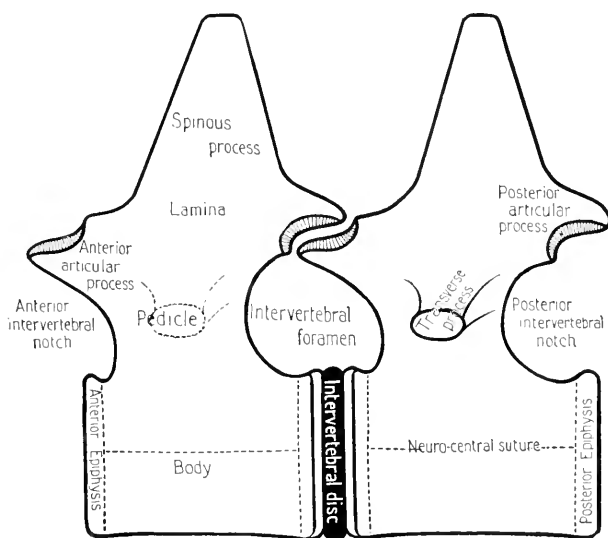
<sup>7</sup> *Lamina*, a thin sheet.

The arches of adjoining vertebrae are joined by means of cephalic and caudal articular<sup>1</sup> processes which project on each side toward the head and toward the tail, usually from the junction of the pedicle and the lamina (Fig. 17). The cephalic articular processes articulate with the caudal articular processes of the preceding vertebra, and the caudal articular processes articulate with the cephalic articular processes of the succeeding vertebra. The transverse processes spring from the sides of the pedicles or from the sides of the body, and are directed in the main transversely to the long axis of the body. A few other processes are found on some



PLAN OF A VERTEBRA. END VIEW.

FIG. 17.



PLAN OF TWO VERTEBRÆ. SIDE VIEW.

vertebræ, but not on all. The cephalic and caudal edges of the pedicles are emarginate, producing the anterior or cephalic and posterior or caudal intervertebral notches, which form with the similar notches

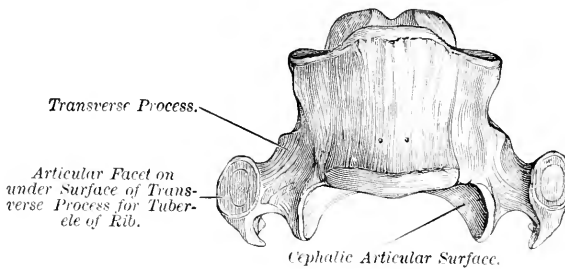
<sup>1</sup> From *articulus*, a joint.

on the adjoining vertebrae **intervertebral foramina** for the exit of the spinal nerves from the neural canal.

The **body** of the vertebra is in general cylindrical. Its cephalo-caudal length is greater than its transverse width, which in turn is always greater than the dorso-ventral height. The body consists of three parts, a middle part, the **centrum proper** or **diaphysis**, and two thin **disks**, one at each end,—namely, the **anterior** or **cephalic** and **posterior** or **caudal epiphyses**. The body presents for examination cephalic, caudal, dorsal, and ventral surfaces, and lateral borders.

The **ventral surface** of the body (Fig. 18) is quadrate and flattened, or strongly convex, transversely. It is limited at the ends by the

FIG. 18.



A THORACIC VERTEBRA, VENTRAL ASPECT.

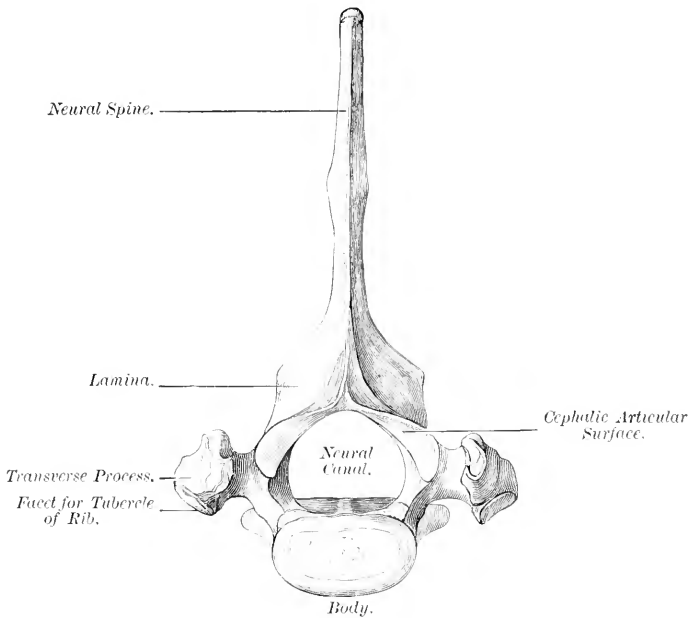
straight or arcuate ventral borders of the cephalic and caudal surfaces. On each of the remaining edges are the lateral border and the root of the transverse process, with the ventral surface of which the ventral surface of the body may be continuous. The ventral surface of the body is slightly concave from the cephalic to the caudal end, and the middle line is often elevated into a decided **keel**, separating shallow excavations. Near each end is an irregular transverse line which indicates the junction of the diaphysis with the epiphysis.

The **dorsal surface** of the body (Fig. 19) forms the floor of the neural canal. It is limited at each end by the dorsal edges of the cephalic and caudal surfaces, and at each side by the medial surface of the ventral end of the pedicle, and by the small lateral border. While the surface is in general flat, the middle line commonly presents a flattened **ridge** wider at the ends than in the middle. On each side of this ridge is a shallow depression, the two together forming most of the dorsal surface. Close to the middle of the median ridge, on each side, is a **vascular foramen**. These two foramina come together

ventral to the ridge, and form a canal leading into the substance of the bone.

The **cephalic** and **caudal surfaces** or ends of the body are transversely oblong. They are smooth, and are firmly united with the ends of the adjoining bodies by means of an intervening plate of fibro-cartilage. In young bones this articulation is usually stronger than the

FIG. 19.



A THORACIC VERTEBRA, ANTERIOR OR CEPHALIC ASPECT.

union between the epiphyses and the body. It is common, therefore, in disarticulated skeletons, to find the body of a vertebra entirely deprived of its epiphyses, or with one or both epiphyses of an adjoining vertebra attached to it in addition to its own. When the epiphysis is lost the end of the body is irregular and roughened (Fig. 20).

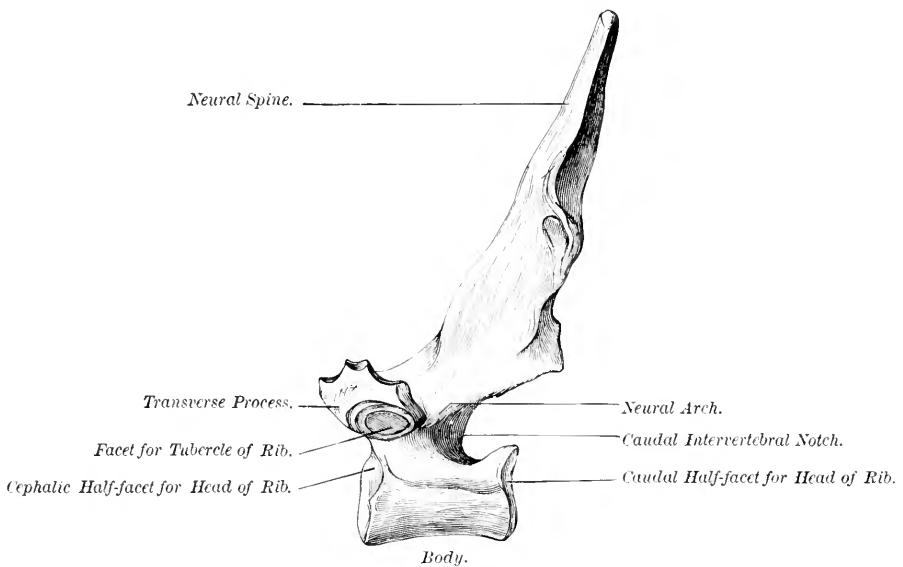
The bodies have no true **lateral surfaces**, since the sides are continuous with the ventral surface or occupied by the roots of the transverse processes and the pedicles. A lateral border where the dorsal and ventral surfaces join appears cephalic to these projections, but more especially caudal to them. This border assists in the formation of the intervertebral notches, and is transversely grooved to increase the size of the intervertebral foramina.

The **neural arch** has almost always a greater width than height. Its width may exceed that of the body, but from cephalic to caudal end it is as long as the body.

The **pedicles** are directed dorsally at right angles to the body.

The **laminæ** have a greater cephalo-caudal diameter than have the pedicles. This increased diameter is principally due to the articular processes, which stand out prominently on each side, but in some cases

FIG. 20.



THORACIC VERTEBRA, SIDE VIEW.

are not entirely distinct from the laminæ. The **articular processes** have smooth **articular surfaces**. The direction of these surfaces serves to distinguish the cephalic processes from the caudal processes, and hence also the cephalic end of the vertebra from the caudal end (Fig. 21). The **cephalic** articular surfaces always **face dorsally** or dorsally and medially. The **caudal** articular surfaces always **face ventrally** or ventrally and laterally.

The lateral surface of the pedicle either is occupied by the root of the transverse process or is free. In the latter case it is gently concave dorso-ventrally, and serves for muscular attachment. The lateral surface of the lamina is usually convex.

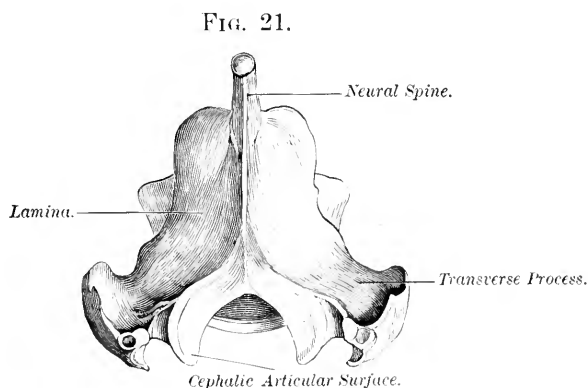
The **inner surface** of the arch is concave from side to side, and either flat or gently convex from the cephalic to the caudal end. It is smooth, and furnishes attachment to the membrane of the spinal cord.



The spinous and transverse processes are subject to so much variation that further description in this place is unnecessary.

**Nomenclature.**—Vertebra (from *vertere*, to turn) was originally used for joints in general, and was applied by Celsus (A.D. 37) to the segments of the spinal column. The Greeks employed *spondylos* or *stropheus* (from *strepho*, to turn). The German name is *die Wirbel*; the French, *la vertèbre*.

**Muscular Attachments.**—The muscles attached to the vertebræ are so numerous and vary so much in form and function in the different regions of the column that a mere list of them, without description and dissection, would be of little value. The student has probably observed, when cleaning the skeleton, that the trunk-muscles may be rudely classified in three groups. In the first group are those which arise from vertebræ and are inserted in the head, the ribs, and the extremities. In the second group are those which form the large complex mass which occupies the furrow on each side of the row of



THORACIC VERTEBRA, DORSAL ASPECT.

spinous processes. They arise from the sacrum and innominate bones, and are directed toward the head and give off slips which have various names and are inserted in the vertebræ of the different regions and in the ribs. In the third group are the many small muscles which, deeply placed and with limited range of motion, stretch from process to process, and give rigidity to the column.

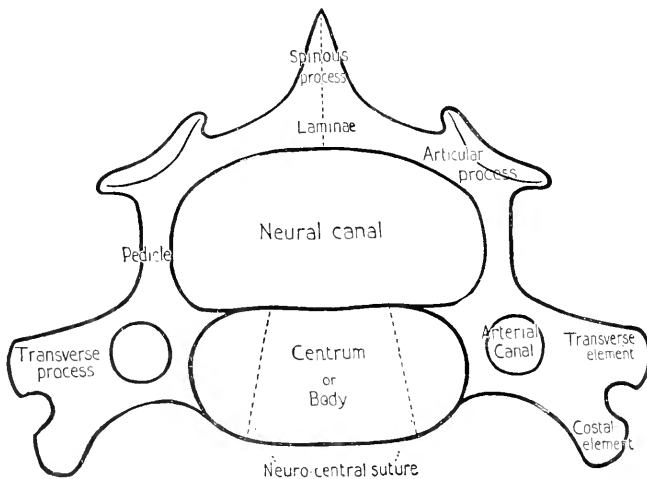
**Ossification.**—The typical vertebra is developed from five principal centres of ossification, whereof three are primary centres,—namely, one for each lateral mass of the neural arch, one for the body proper; and two are secondary centres,—namely, one for each epi-

physis of the body. The centres for the lateral masses assist also in the formation of the body; the neuro-central sutures, which in young bones are seen separating the parts, therefore cut off considerable portions of the body at the sides (Fig. 22). The tips of the spinous and transverse processes, which for a long time remain cartilaginous, eventually ossify from separate centres.

### CERVICAL VERTEBRÆ.

The Cervical Vertebrae have a number of characters in common which readily distinguish them from the vertebrae of the other regions. With the single exception of the seventh cervical vertebra, all may be recognized at once by the **foramen** which is seen on the cephalic and the caudal aspect of the bone at the root of each transverse process, close to the body (Fig. 22). These foramina are the openings of a

FIG. 22.



PLAN OF A CERVICAL VERTEBRA. END VIEW.

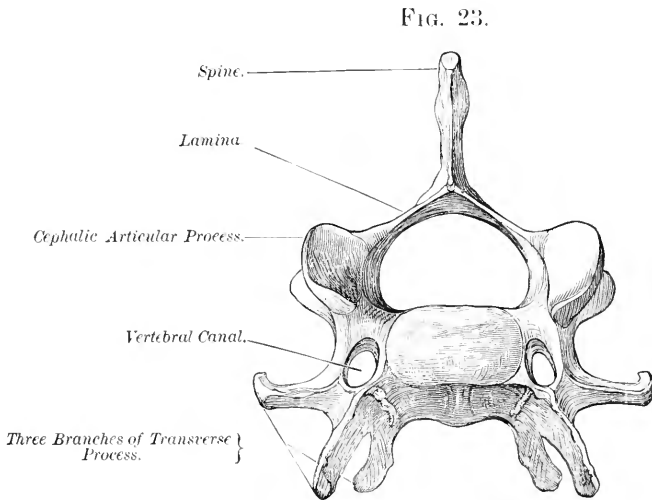
cephalo-caudal canal piercing the transverse process and giving passage to the vertebral artery. The seventh cervical vertebra has no such canal in its transverse processes, and is to be recognized by the absence of the characters peculiar to the thoracic, lumbar, and caudal vertebrae, and by its general resemblance to the other cervicals.

The first and second cervical vertebrae are so unlike the rest that they must be described separately.

A TYPICAL CERVICAL VERTEBRA.

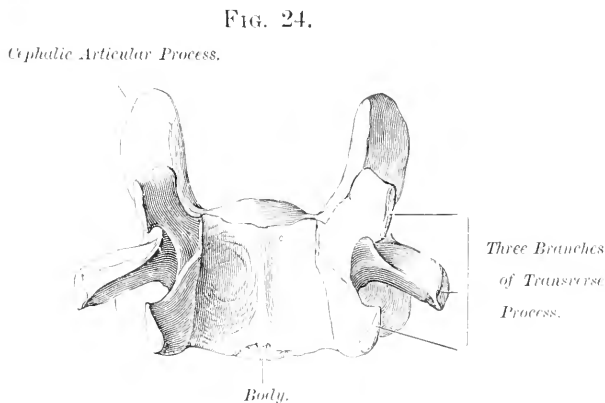
The **Sixth Cervical** may be taken as the type ; it shows the greatest development of all the peculiar characters (Fig. 23).

The **body** of the sixth cervical is wide and much flattened from the dorsal to the ventral side. The **ends** are bevelled,—the cephalic



A CERVICAL VERTEBRA, ANTERIOR OR CEPHALIC ASPECT.

at the expense of the ventral surface, the caudal at the expense of the dorsal surface (Fig. 27). The **ventral surface** is flat and keeled (Fig. 24). It forms the floor of a deep fossa whereof the walls are the transverse processes.



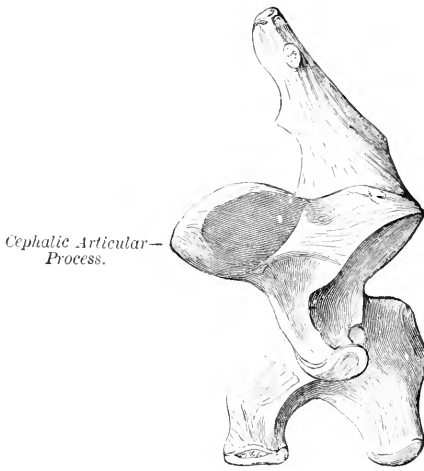
SIXTH CERVICAL VERTEBRA, VENTRAL ASPECT.

The **pedicles** have small cephalo-caudal and greater dorso-ventral diameters. Their dorsal ends are directed toward the head, and somewhat laterally from the middle line. They form an angle of about

thirty degrees with the laminae. The lateral surface faces toward the tail as well as laterally, and is excavated at the caudal part.

The cephalic articular processes appear to be continuations of the

FIG. 25.



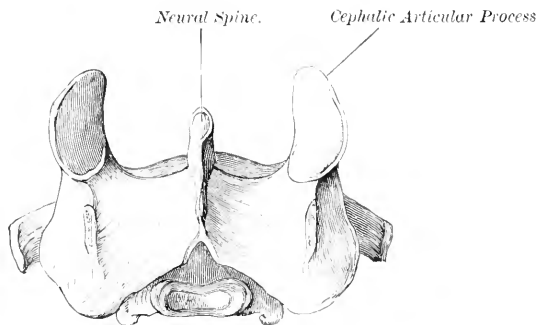
A CERVICAL VERTEBRA, SIDE VIEW.

pedicles, in a dorsal and cephalic direction, and the caudal articular processes are the ventral lateral free corners of the laminae (Fig. 25).

The intervertebral notches, especially the caudal, are distinct, but are not so much emarginations on the edges of the pedicles as spaces between the body, the pedicle, and the articular process.

The laminae have a small cephalo-caudal diameter, but are wide transversely (Fig. 26). They are placed almost horizontally, and lie

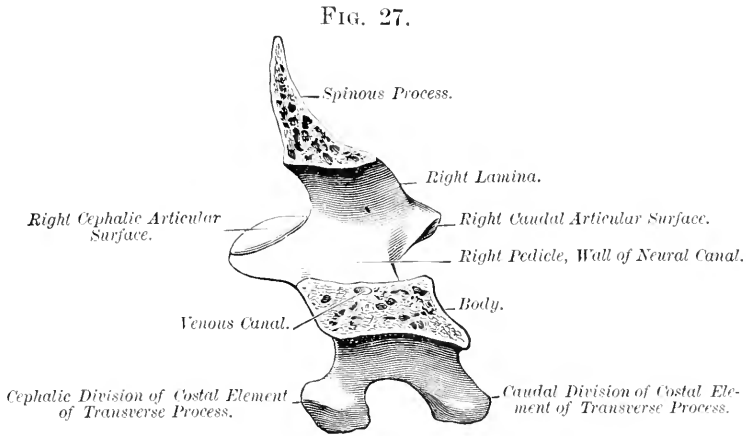
FIG. 26.



SIXTH CERVICAL VERTEBRA, DORSAL ASPECT.

largely caudal to the pedicles. The cephalic margin is straight, but the caudal margin is incised in the middle line.

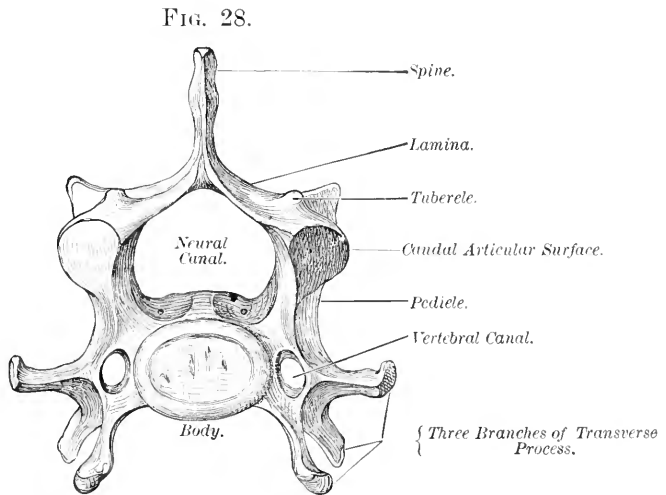
The cephalic articular surfaces face dorsally and medially; the caudal articular surfaces face ventrally and laterally. The neural canal is wide and high, but not long (Figs. 27 and 28). The spinous



SIXTH CERVICAL VERTEBRA. LONGITUDINAL VERTICAL SECTION.

process is about as long as the neural canal. It is flattened from side to side, and pointed at the end, which is sometimes turned toward the tail. Its general direction is dorsal and cephalic. The striking peculiarity of this vertebra lies in the form of the transverse processes.

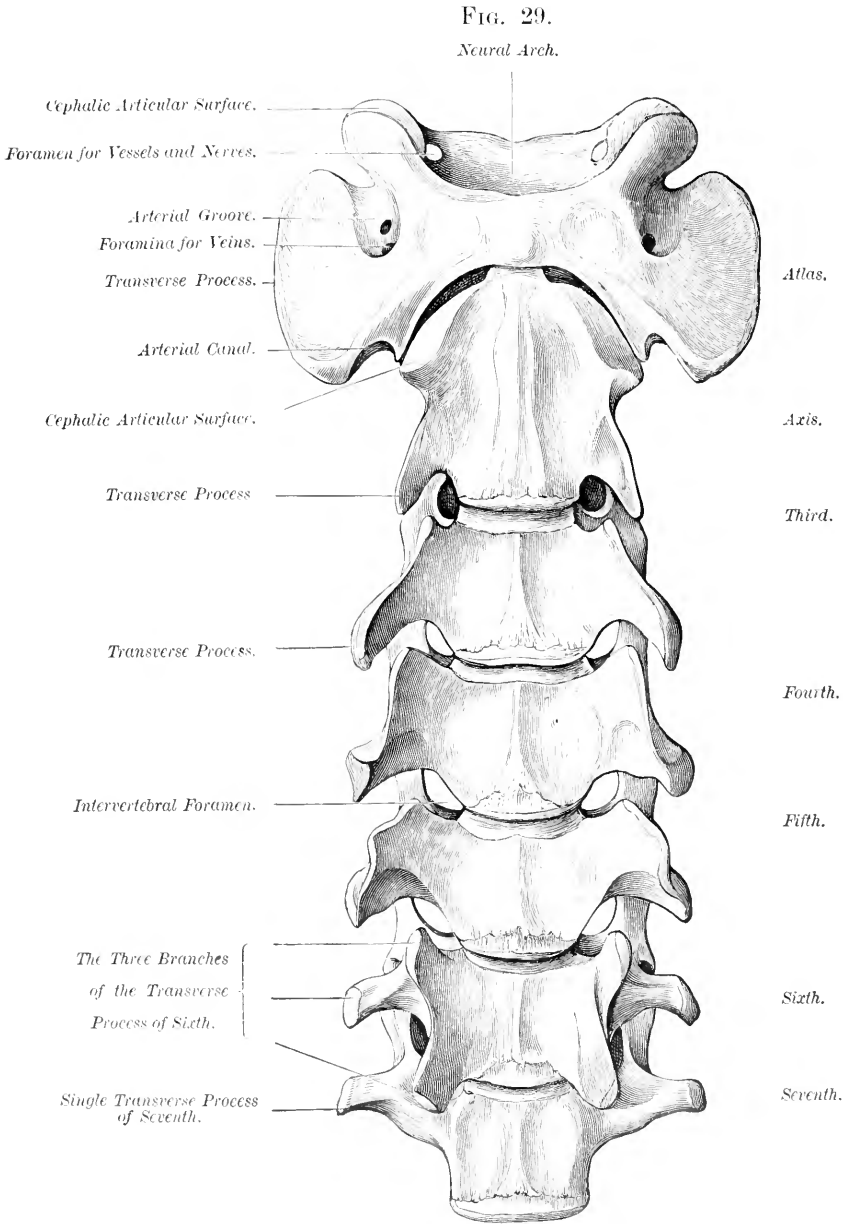
Each transverse process has a short basal portion pierced by the arterial canal (Fig. 28). The dorsal wall of the canal is thicker than



A CERVICAL VERTEBRA, POSTERIOR OR CAUDAL ASPECT.

the ventral wall. From the basal portion two branches arise,—namely, the dorsal and the ventral. The dorsal branch, known as the

transverse element, is moderately long, with small dorso-ventral and cephalo-caudal diameters, and is directed almost at right angles to the



THE CERVICAL VERTEBRÆ, VENTRAL ASPECT.

median plane or slightly dorsally, and also toward the tail. It is of almost equal cephalo-caudal width through its entire length, but its cephalic lateral angle is rounded. The ventral branch is called the costal<sup>1</sup> element, because it occupies the same position in the cervical

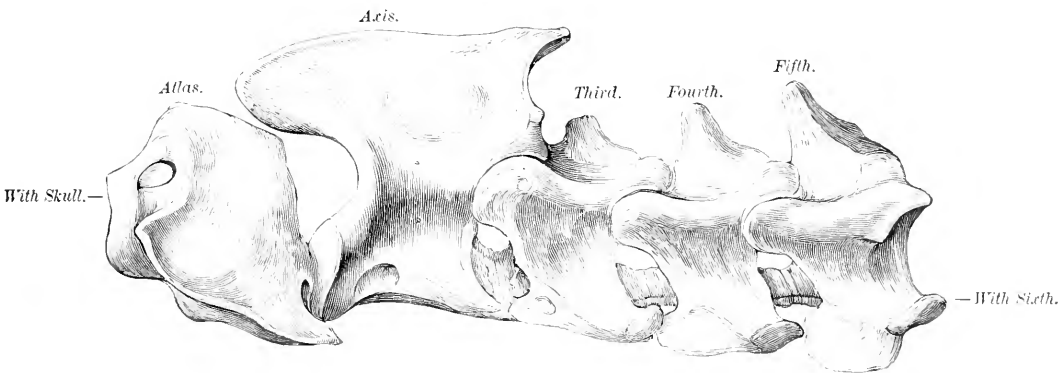
<sup>1</sup> From *costa*, a rib.

that the rib occupies in the thoracic vertebræ. It is about as long as the other element, but is directed ventrally and also slightly laterally and toward the tail. Its cephalo-caudal diameter is much greater than that of the dorsal branch, and of the common basal portion. It is divided by an emargination of varying depth into cephalic and caudal parts (Fig. 27), thus producing with the transverse element **three branches** to the transverse process.

**CHARACTERS OF THE REMAINING CERVICAL VERTEBRÆ.**

The **Seventh Cervical Vertebra** has no arterial canal in its transverse process. Its **spinous process** is much longer than the spinous processes of the other cervicals, and points dorsally. Its **transverse process** is a simple bar directed transversely and slightly ventrally. The seventh cervical differs from the first thoracic in that it bears

FIG. 30.



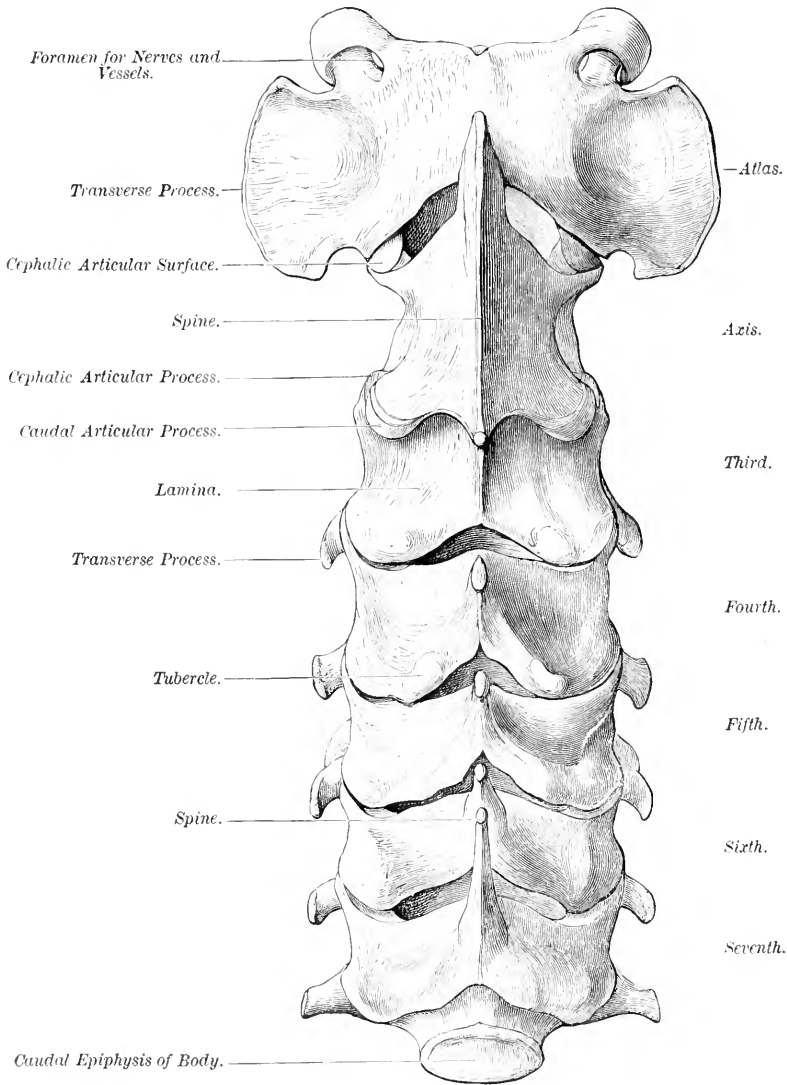
FIRST FIVE CERVICAL VERTEBRÆ, SIDE VIEW.

on the ventral surface of its transverse process no articular facet for the tubercle of a rib. It differs from the sixth in the following additional characters: The **body** has a greater transverse diameter, but a smaller cephalo-caudal diameter. The **pedicles** are more extended dorso-ventrally and from the cephalic to the caudal end. The **laminæ** slope more dorsally toward the spine, and the **neural canal** is larger and more arched. The **cephalic articular processes** are longer.

The **Fifth Cervical Vertebra** (Figs. 29, 30, 31) closely resembles the sixth and the fourth. It can be distinguished from the sixth by the **transverse process**, which is not divided at the end into three branches.

It can be distinguished from the fourth by the neural arch, which has a shorter cephalo-caudal diameter than the arches of any of the first four vertebræ. It has the following minor points of difference

FIG. 31.



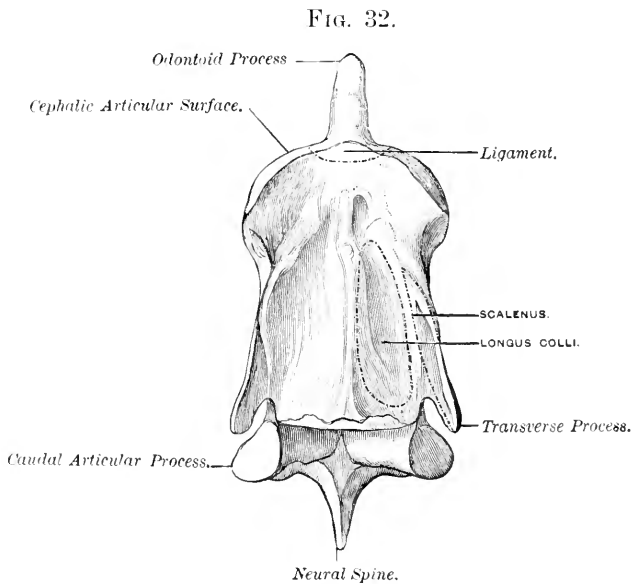
THE CERVICAL VERTEBRÆ, DORSAL ASPECT.

from the sixth: The body is longer and wider. The cephalo-caudal diameter of the pedicles and of the laminæ is considerably greater. The spinous process is shorter; the neural canal is more round. The cephalo-caudal diameter of the transverse process is much less, and, although the process consists of the transverse and costal elements, they are to a certain extent coalesced, lateral to the arterial canal.



The costal element, moreover, is shorter and directed more laterally, and is not divided into cephalic and caudal parts. The transverse element has a more caudal inclination.

The **Fourth Cervical Vertebra** (Figs. 29, 30, 31) may be recognized by the cephalo-caudal length of its arch, which is greater than the length of the arch of the fifth and less than that of the third. The **spinous process** is shorter than the spinous process of the fifth, but longer than that of the third. The **laminæ** are but slightly inclined dorsally, and the **neural canal** is smaller. The caudal border of each lamina is arcuate. At the middle of its dorsal surface, near the border, is a swelling known as the **tubercle**. The **cephalic articular processes** are shorter, and their **articular surfaces** do not face so much toward the middle line. The transverse and costal elements of the transverse process coalesce beyond the arterial canal



THE AXIS, VENTRAL ASPECT.

through almost their entire extent. The caudal end of the costal element is reduced in size, and the end of the transverse element sometimes appears as an oval tubercle at the ventral caudal part of the lateral surface. The fourth vertebra, as a whole, is transversely narrower than the fifth vertebra.

The **Third Cervical Vertebra** (Figs. 29, 30, 31) is easily recognized by the greater cephalo-caudal length of its arch, by the almost

complete absence of a **spinous process**, and by the simple character of the end of its **transverse process**.

The **laminae** are still more inclined toward the middle line, and their **caudal margins** are more arcuate. The **tubercles** are well marked. The **cephalic articular processes** are shorter. The **pedicles** are vertical. The **neural canal** is smaller and more nearly round. The **transverse processes** have a greater cephalo-caudal diameter and a more caudal direction. Their costal element is often reduced to a small strip attached to the ventral edge of the transverse element. The whole vertebra is longer and narrower than the fourth.

The **Second Cervical Vertebra** is known as the **Axis**. It is recognized at once as the longest and narrowest of all the cervicals.

The **body** is rectangular, with the cephalo-caudal length twice the transverse width; it is flat from the dorsal to the ventral side. Its cephalic end is prolonged, in the middle line, into a conical **odontoid process**, which articulates with the dorsal surface of the body of the first cervical, called the atlas.

The **ventral surface** of the body (Fig. 32) is contracted transversely at a point cephalic to the middle of the cephalo-caudal diameter. The region cephalic to this contraction is flat, or slightly concave from side

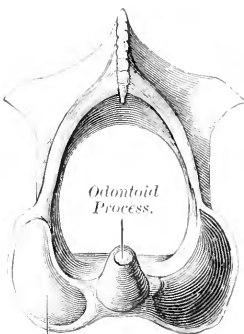
to side; but, caudal to the contraction, the surface has a strong median keel flanked by decided excavations.

The **cephalic end** of the body (Fig. 33), on each side of the odontoid process, slopes in a lateral and caudal direction. It is arcuate and swollen, and forms the ventral part of the cephalic articular process.

The **odontoid process** (Fig. 34) is a conical mass, scarcely twice as long as wide, directed toward the skull and dorsally from the middle line of the body. Its **ventral surface** is occupied by a smooth, transversely convex area (sometimes a decided facet concave in a cephalo-caudal line) for articulation with the dorsal surface of the ventral bar of the atlas.

Each **transverse process** (Fig. 34) springs from the caudal part of the side of the body. It is small, simple, and sharp at the end, which

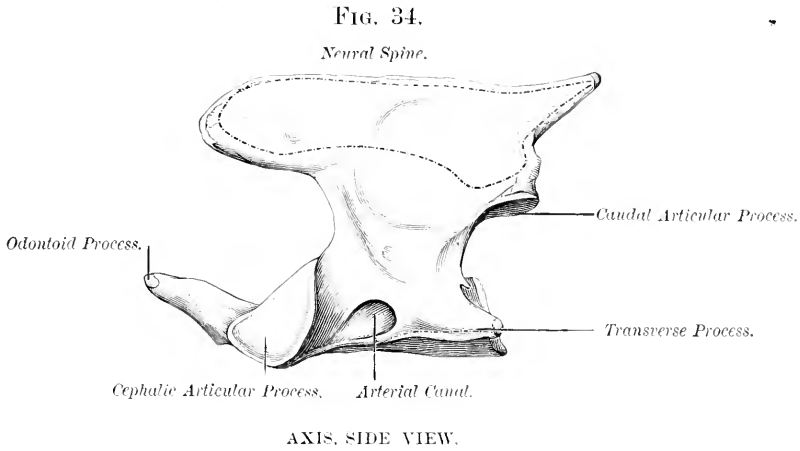
FIG. 33.



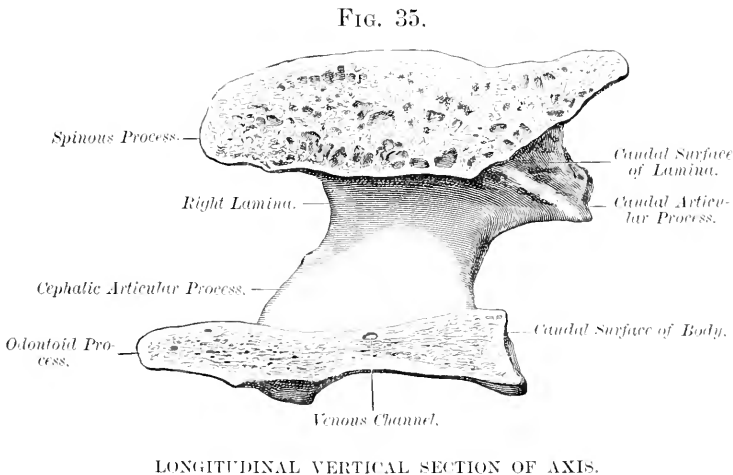
*Cephalic Articular Process.*

AXIS, ANTERIOR OR CEPHALIC ASPECT.

points almost directly toward the tail. The **arterial canal** is large, and is continued forward as a **groove** on the body beyond the base of the transverse process.



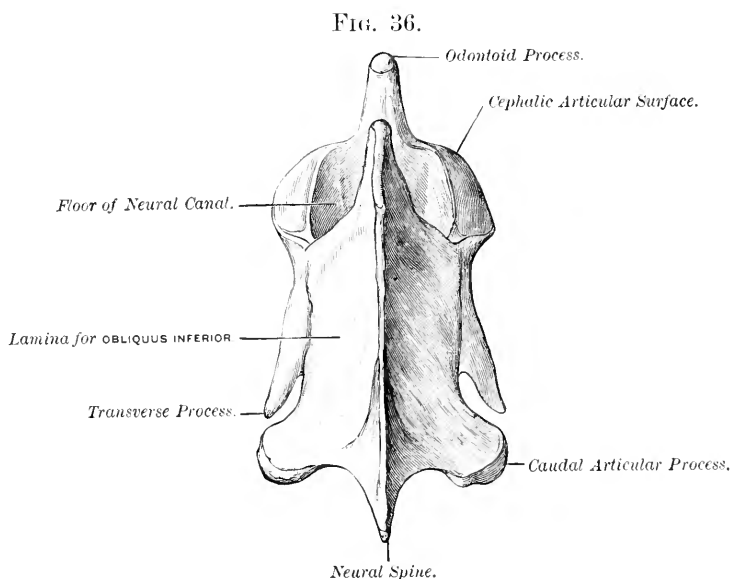
The **pedicles** are about as long in a cephalo-caudal line as the pedicles of the third cervical; they are, however, higher. They are almost at right angles to the bone in their caudal part, but slope toward the middle line in their cephalic part. The **neural canal** is high, but narrower than the canal in any of the other cervicals (Figs. 32, 35).



The **intervertebral notches** are well marked. The **cephalic articular process** is situated on the cephalic edge of the body, and is continued dorsally on the ventral part of the pedicle. It is a pear-shaped swelling with a narrow dorsal end and a wide ventral end. Its **articular surface** is gently convex, more strongly in the dorso-

ventral than in the cephalo-caudal direction. It faces laterally, dorsally, and toward the head. The **caudal articular process** is the caudal ventral angle of the lamina which overhangs the caudal intervertebral notch. Its oval articular surface faces ventrally and slightly laterally and toward the tail.

The **laminæ** (Fig. 36) are long, and the **spinous process** is a long keel, produced at the cephalic end into a laterally compressed process overhanging the cephalic intervertebral notch of the lamina. The laminæ are directed more vertically to the body at the cephalic end



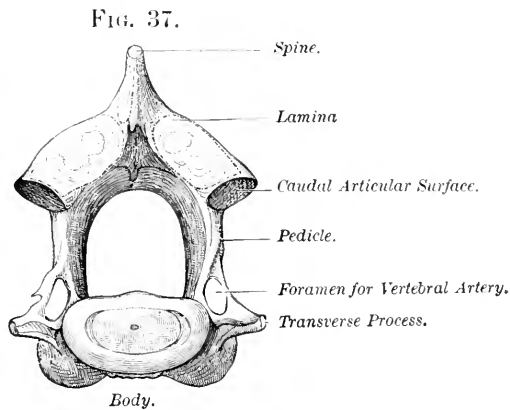
than at the caudal end; the cephalic part of the lateral surface therefore faces laterally and only slightly dorsally, while the caudal part faces equally laterally and dorsally. The lateral surface is depressed, and gives attachment to the obliquus capitis inferior muscle.

The caudal part of each lamina (Fig. 37) is so thick that a caudal surface is produced. This surface lies between the caudal end of the spine and the caudal articular surface. It is quadrate, faces ventrally, medially, and toward the tail, and is rough for the attachment of a strong cervical muscle.

**Nomenclature of the Axis.**—The axis is so termed from the Greek *axion*, because it is the axis on which the first vertebra, or the atlas, turns. The name *epistrophæus*, now generally used in Germany for this bone, was given to it by Heister (A.D. 1683–1758) some time after

it had been abandoned as the name of the atlas. The common German and French terms are mere translations of the phrase, the second cervical vertebra.

**Ossification of the Axis.**—In addition to the five principal centres of ossification common to all vertebrae, the axis has four more, representing those of the body of the atlas which coalesces with it. These additional centres are one at the tip and one in each side of the odontoid process, and one in the caudal epiphysal plate, usually



THE AXIS, POSTERIOR OR CAUDAL ASPECT.

coalesced with the cephalic epiphysal plate of the true body of the axis. Smaller ossifications are said to appear late on the edge of the spinous process and on the tip of the transverse process.

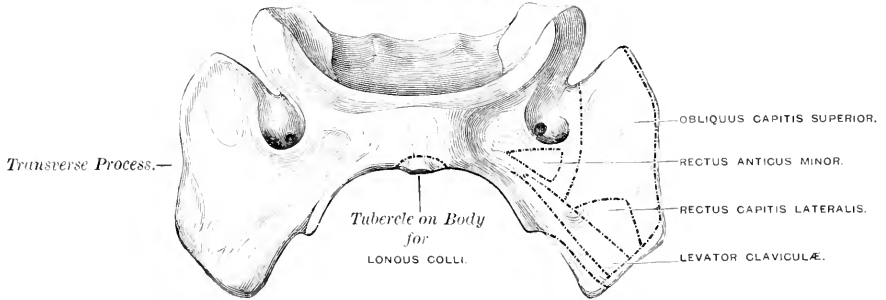
The **First Cervical Vertebra**, or the **Atlas**, differs from all the rest by its large, wing-like, transverse processes and by the absence of a spinous process, but especially by the rudimentary condition of the body; the true body has been joined to the second vertebra to form its odontoid process.

What in other vertebrae is the body is here merely a bony bar uniting the lateral masses on the ventral side (Fig. 38). This bar is about twice as wide as it is long; the ventral surface is convex and the dorsal surface is concave. The cephalic margin is straight; the caudal margin is emarginate, but presents at the middle a small **tubercle**, which gives attachment to the longus colli muscle.

The **neural arch** (Fig. 39) has a greater cephalo-caudal diameter than the ventral arch. It is not so high as the neural arch of the second vertebra. It is extremely thin and regularly convex from side to side, there being no real division into pedicles and laminae.

The dorsal aspect of the arch is smooth. The cephalic margin is straight or slightly arcuate in the middle, and prolonged at each side into the prominent cephalic articular process. The middle part of the cephalic margin gives attachment to the rectus capitis posticus

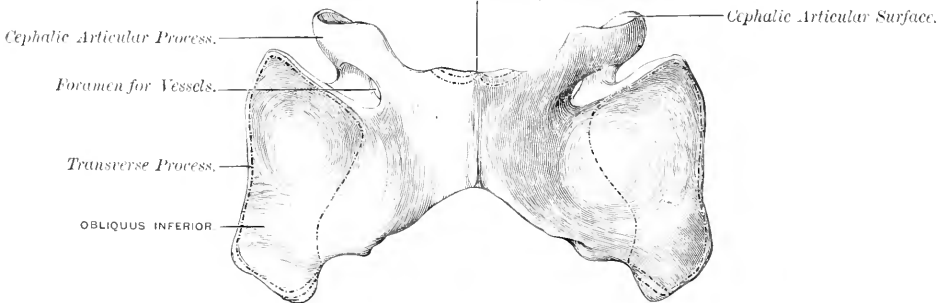
FIG. 38.

*Cephalic End, with Skull.*

THE ATLAS, VENTRAL ASPECT.

minor muscle. At a point a couple of millimetres caudal to the cephalic margin, at the median end of the cephalic articular process, is a foramen which pierces the bone transversely. A well-marked groove is continued laterally and ventrally from this foramen on the arch and cephalic to the cephalic edge of the transverse process. It then passes toward the tail, and medially on the ventral aspect of the root of the transverse process to the cephalic opening of the arterial

FIG. 39.

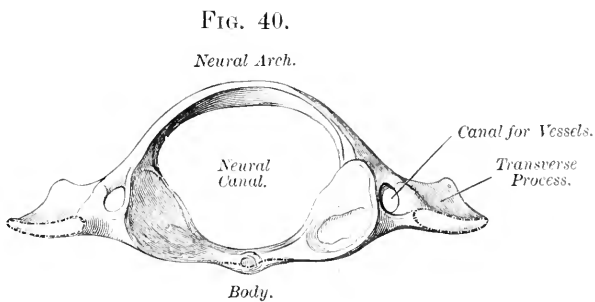
*RECTUS POSTICUS MINOR on Front of Neural Arch.*

THE ATLAS, DORSAL ASPECT.

canal. The vertebral artery, after traversing the arterial canal in the transverse process, is lodged in this groove, and enters, through this dorsal foramen, the neural canal, whence it is continued into the cranial cavity of the skull. The foramen also gives exit to the first spinal

nerve. Caudal to the foramen and groove, the dorsal surface slopes ventrally and becomes continuous with the dorsal surface of the transverse process. The caudal margin of the arch is thin and deeply emarginate. Its prominent lateral ends are continued ventrally into the arcuate caudal edge of the caudal articular process.

The **transverse processes** are thin, ear-shaped plates directed laterally from the sides of the ventral part of the arch. The cephalo-caudal diameter of each process is shorter at the root than at the lateral edge. The dorsal surface (Fig. 39) is excavated for the attachment of the obliquus capitis inferior muscle. Its caudal margin is arched transversely and pierced close to the neural arch by the arterial canal. This canal does not extend through the entire length of the process, but appears again on the ventral aspect cephalic to the middle, and is continued as the groove already mentioned. The medial wall of the canal is pierced at the cephalic end by a foramen, which leads into the neural canal and transmits a vessel. The ventral surface of the transverse process (Fig. 38) is smooth and almost flat. It gives attachment to the following muscles: on the cephalic two-thirds, to the obliquus capitis superior; on the caudal third, to the rectus capitis lateralis and levator claviculae; on a small triangular area just medial and caudal to the cephalic opening of the arterial canal, to the rectus anticus minor.

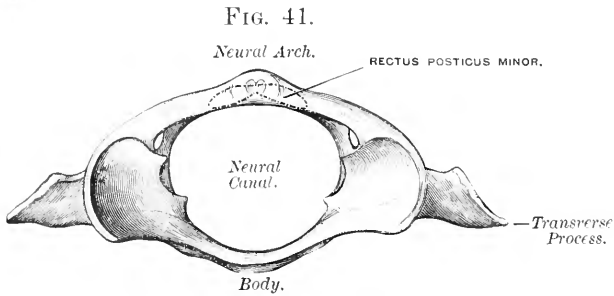


THE ATLAS. POSTERIOR OR CAUDAL ASPECT.

The caudal articular processes are not distinct (Fig. 40). Each is that expanded median part of the caudal edge of the transverse process which is directed to face medially and toward the tail. The articular surface is slightly concave, and encroaches on the caudal margin of the so-called body.

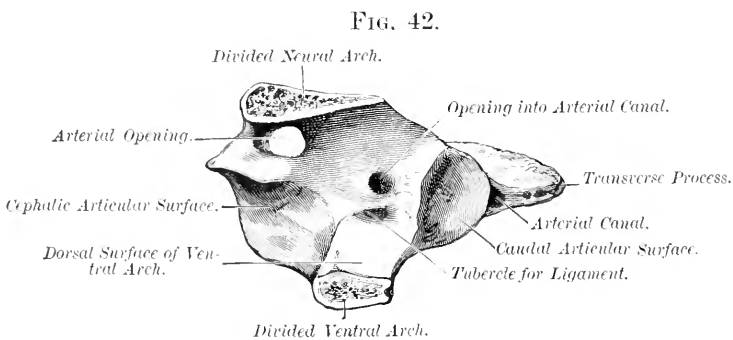
Each cephalic articular process (Fig. 41) is thin, laterally strongly convex and medially deeply concave from the dorsal to the ventral

edge. The articular surface is pear-shaped and cup-like. It faces toward the skull and the middle line, and articulates with the condyle of the occipital bone.



THE ATLAS. ANTERIOR OR CEPHALIC ASPECT.

The neural canal appears to be round, but is divided into two parts by a transverse ligament, which arises on each side from a **tubercle and depression** (Fig. 42) situated just caudal to the cephalic articular surface, decidedly ventral to the middle of the medial wall of the arch. The dorsal of the two canals thus formed is the **neural canal** proper, and its outline is a little more than a half-circle. The ventral canal receives the odontoid process of the second vertebra. Its outline is less than half of a smaller circle. The dorsal surface of the ventral bar is smooth for articulation with the odontoid process, which is held firmly in place by the transverse ligament and by the check ligaments which run from its tip to the occipital bone of the skull. The medial surface of the arch, dorsal to the tubercle, is smooth, and



ATLAS. LONGITUDINAL VERTICAL SECTION.

exhibits, dorsal to the cephalic articular surface, the large opening for the vertebral artery, and, just dorsal to the tubercle, the smaller opening into the arterial canal. The atlas has a greater range of motion than any other vertebra except the terminal caudals. In



addition to the motions common to all vertebrae,—namely, the dorso-ventral and, to a less degree, the lateral,—it rotates round the odontoid process.

**Nomenclature of the Atlas.**—The term atlas is used because this vertebra supports the head, as Atlas was fabled to support the globe. The word was introduced into anatomy by Vesalius (A.D. 1514–1564). It had been known previously as the *epistropheus* (from Greek *epi*, upon, and *stropho*, to turn), the vertebra turning on the others; or as *protos spondylus*, the first vertebra. The Germans call it, in addition to *der Atlas*, *der Träger*; and the French *la première vertèbre cervicale*.

#### RECAPITULATION OF CHARACTERS OF CERVICAL VERTEBRÆ.

The **body** gradually increases in transverse width and reaches its maximum in the seventh. The cephalo-caudal diameter is greatest in the axis and decreases in the following order: the third, the fourth, the fifth, the sixth, the seventh, the atlas.

The **neural arch** is dorso-ventrally highest in the axis, and decreases in height as follows: atlas, seventh to third. It is transversely widest in the atlas, and then decreases from the seventh to the axis. The cephalo-caudal diameter is greatest in the axis, and decreases as follows: the third, the atlas, the fourth, the fifth, the seventh, and the sixth.

The **spinous process** is longest in the seventh; shorter in the axis and from the sixth progressively to the third. Its cephalo-caudal diameter is greatest in the axis. It is absent in the atlas and rudimentary in the third. The spinous processes are directed toward the skull.

The **transverse processes** have the greatest cephalo-caudal diameter in the atlas; this diameter then decreases usually in the following order: the sixth, the third, the fourth, the fifth, the axis, the seventh. They are longest from root to tip in the atlas, and then decrease from the fourth, the seventh, the third, to the axis. They are most complex in the sixth and most simple in the axis. The transverse processes arise from the body, and not dorsally from the pedicles.

The **arterial canal** is found in all except the seventh. In the atlas it does not traverse the entire cephalo-caudal width of the process.

The **cephalic articular processes** spring from the pedicles, and the **caudal articular processes** appear to be parts of the laminae.

The following table will be of service in quickly recognizing the different cervical vertebræ. The numbers refer to the vertebræ. The body is always ventral; the cephalic articular surfaces face dorsally.

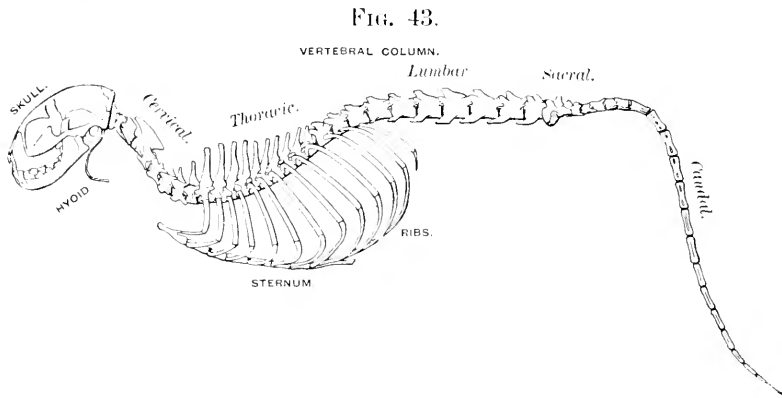
TABLE.

An arterial canal in the transverse process.	
No body; flat, wing-like transverse process . . . . .	Atlas
A distinct body.	
Tooth-like ( <i>odontoid</i> ) process projecting from cephalic end of body . . . . .	Axis
No odontoid process.	
Spinous process rudimentary; laminae with greater cephalo-caudal diameter . . . . .	3
Spinous process distinct; laminae with lesser cephalo-caudal diameter.	
Ventral or costal element of transverse process undivided.	
Cephalo-caudal diameter of laminae greater, spinous process shorter, costal element coalesced with transverse element . . . . .	4
Cephalo-caudal diameter of laminae less, spinous process longer, costal element more free . . . . .	5
Costal element divided into cephalic and caudal branches . . . . .	6
No arterial canal in transverse process . . . . .	7

THE THORACIC VERTEBRÆ.

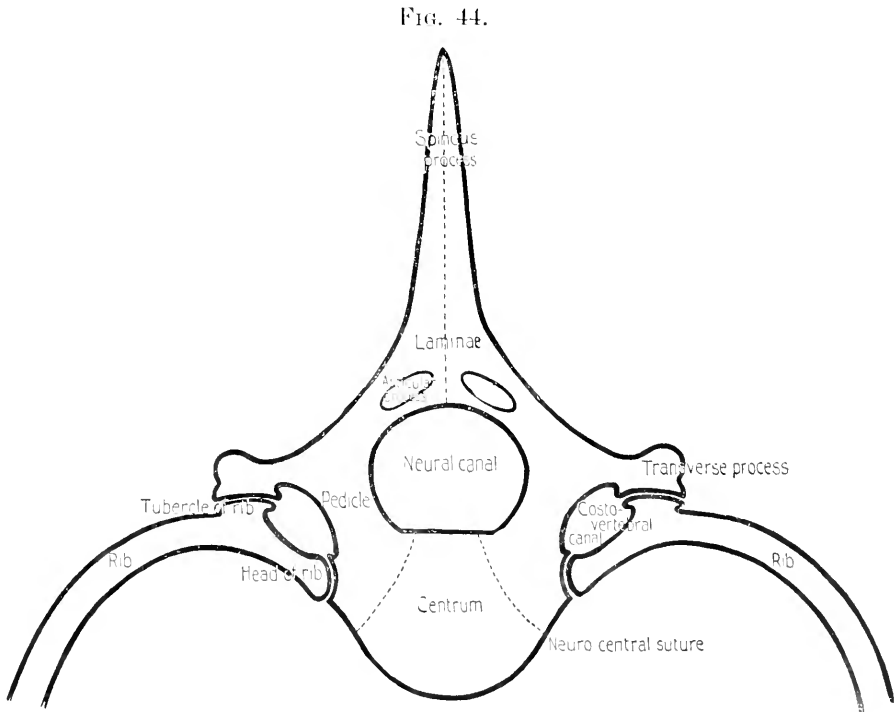
The thirteen Thoracic Vertebrae are generally called the Dorsal Vertebrae,—an obviously misleading term; not they alone, but all vertebræ are on the dorsum or back of the skeleton. They are **thoracic**; situated in the region of the **thorax**, or chest, between the cervical and the lumbar vertebræ (Fig. 43). Most of them can be recognized at once by their small bodies and their long, pointed spinous processes. The thoracic vertebræ, moreover, furnish attachments to the dorsal ends of the ribs (Fig. 44); hence the **facets** on the sides of the bodies for these articulations are common to them all. Since, as a rule, the ribs

articulate at the junction of two vertebrae, the articular facets on the bodies are divided into halves, a half being on each of the contiguous



THE AXIAL SKELETON. (Greatly reduced.)

vertebrae. In most cases these half-facets are situated mainly upon the epiphyses of the body; therefore, if an epiphysis be lost, the greater part of the facet will be lost also. It should be remembered that the



PLAN OF A THORACIC VERTEBRA. END VIEW.

side of the body of the first thoracic vertebra has one entire facet at the cephalic end for the first rib and a half-facet on the caudal end for

the second rib. Each succeeding vertebra has two half-facets, one at each end, until the eleventh is reached, where the articulation for the rib is more caudal; wherefore the eleventh, twelfth, and thirteenth vertebrae have each a single entire facet.

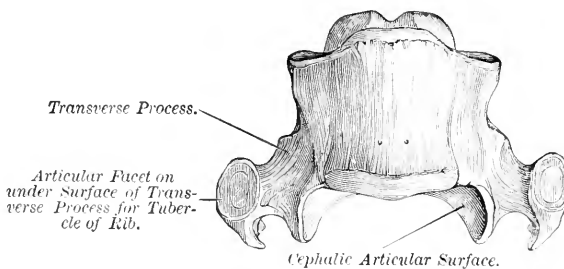
With the exception of the first, the eleventh, the twelfth, and the thirteenth rib, every rib is cephalic to its own vertebra; for example, the seventh rib is attached between the sixth and seventh vertebrae. Another character common to all the thoracic vertebrae (except the last three) and useful for rapid identification is found in the smooth **articular facet** on the ventral surface of the transverse process. This facet joins the tubercle of the rib.

The cephalic thoracic vertebrae have the general form of the last cervicals; the caudal thoracic closely resemble the cephalic lumbar. A typical thoracic vertebra should be therefore selected from the middle of the region.

#### A TYPICAL THORACIC VERTEBRA.

The **Sixth Thoracic Vertebra**.—The body has equal cephalo-caudal and transverse diameters, but it is somewhat flattened from the dorsal to the ventral side. The **dorsal surface** is quadrate and flat.

FIG. 45.



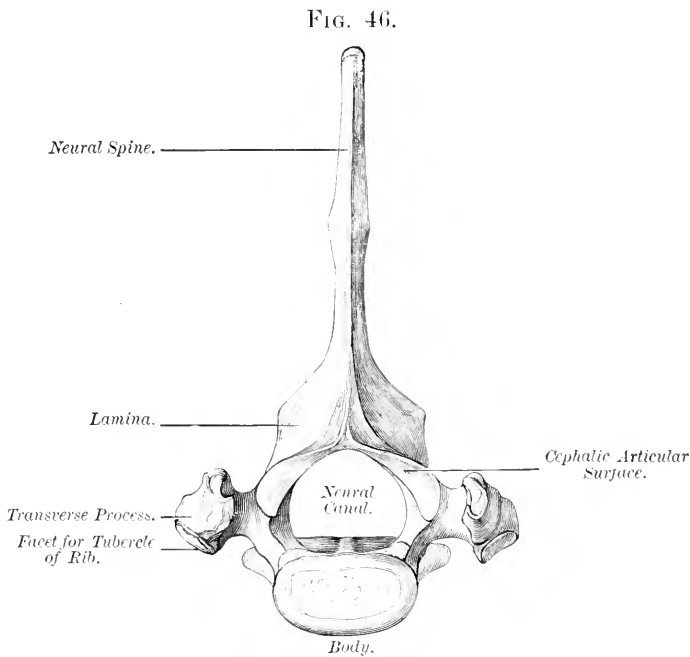
A THORACIC VERTEBRA, VENTRAL ASPECT.

The **ventral surface** (Fig. 45) is convex from side to side and decidedly concave from the cephalic toward the caudal end.

The outline of the **cephalic surface** (Fig. 46) is approximately a circle, a small arc only being cut from the dorsal side. The margin is sharp and well defined dorsally and ventrally, but at each lateral dorsal angle it is rounded and presents the rather obscure **cephalic half-facet** for part of the head of the sixth rib. The **caudal surface** (Fig. 47) is triangular; each dorsal lateral angle is prolonged into a small process. This process exhibits on its caudal surface the half-

facet for the head of the seventh rib, and by its cephalic surface forms a small ventral and caudal wall to the intervertebral notch. The facet for the head of the rib faces toward the tail and slightly laterally.

The **pedicles** (Fig. 48) are perfectly distinct from the body and from the laminae. Their cephalo-caudal diameter is equal to two-thirds of that diameter of the body; their dorso-ventral diameter is equal to half the transverse width of the body. They slope laterally

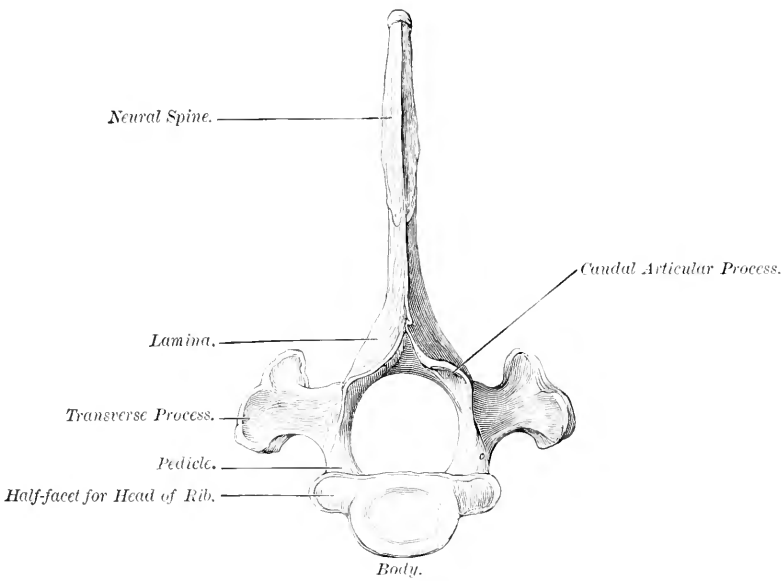


and dorsally. The **cephalic intervertebral notch** is not well marked. The **caudal intervertebral notch** is deep, has an outline of more than a half-circle, and forms most of the intervertebral foramen.

The **transverse process** has a dorsal origin at the junction of the pedicle and the lamina. It is prismatic in form, presenting dorsal, ventral, cephalic, and lateral surfaces, and a caudal border. The dorsal surface is almost square, and gently concave in all directions. It faces toward the tail as well as dorsally. The cephalic surface has the transverse diameter greater than the dorso-ventral diameter. It is limited on the medial side by the cephalic edge of the pedicle, and laterally by the rough, prominent cephalic border of the lateral surface. It is concave transversely, and faces dorsally and toward

the head. The lateral surface is triangular, wide at the cephalic end and pointed at the caudal end. It is irregular, and rough for mus-

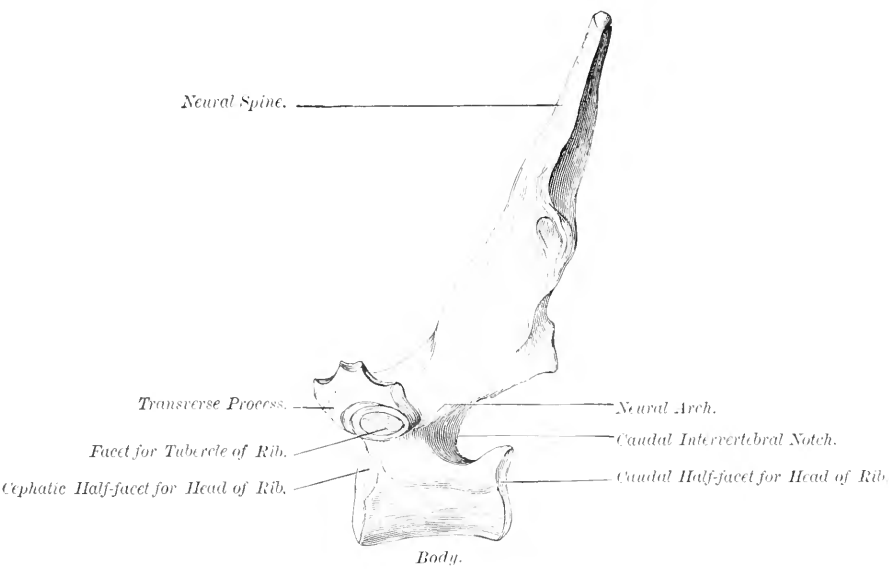
FIG. 47.



A THORACIC VERTEBRA, POSTERIOR OR CAUDAL ASPECT.

cular attachment, and faces in a lateral, cephalic, and dorsal direction. The ventral surface (Fig. 45) consists of a lateral and a medial

FIG. 48.

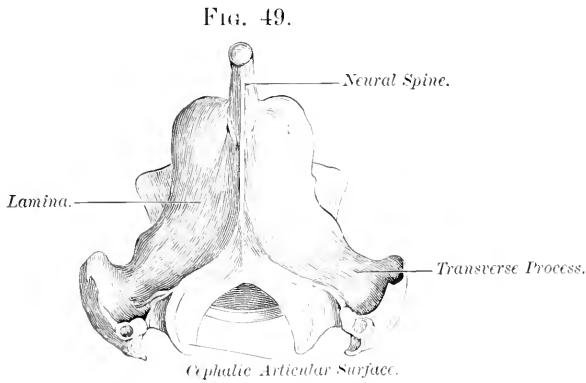


THORACIC VERTEBRA, SIDE VIEW.

part. Of these parts the medial is the larger, and is depressed and

concave from side to side. The lateral part is an oval, raised, articular surface, which is more or less concave from the cephalic to the caudal end and convex transversely. It faces ventrally and slightly laterally, and fits over the corresponding raised facet on the body of the rib known as the tubercle. The caudal border also consists of two parts. The medial part is very short transversely, is deeply emarginate, and its medial end is continuous with the dorsal edge of the lateral surface of the body. The lateral part is directed from the medial part toward the head as well as laterally, and is the caudal part of the lateral margin of the facet on the ventral surface.

The laminæ (Fig. 49) taken together have a cephalo-caudal



THORACIC VERTEBRA, DORSAL ASPECT.

diameter twice as great as the transverse diameter. At the cephalic end they are almost parallel to the dorsal surface of the body for a short distance, but in their caudal part they slope dorsally and toward the tail and project far beyond the body.

The spinous process rises from the caudal half of the dorsal surface and is directed toward the tail, and dorsally. Its dorso-ventral length is twice as great as the cephalo-caudal diameter of the body; and it is compressed laterally and pointed at the end, which is sometimes bent slightly in a caudal direction. In well-developed vertebrae, on each lateral surface of the spinous process, not far from the tip, is a distinct tubercle for muscular attachment.

The cephalic edge of the laminae presents a deep, median, semi-circular emargination. On each side of this emargination the edge is slightly prolonged on the cephalic articular process. The dorsal surface of this prolongation, as well as the dorsal surface along the

edges of the emargination, bears a crescentic, smooth, **cephalic articular surface** which faces dorsally. The rest of the dorsal surface of each lamina faces in its cephalic part dorsally and in its caudal part dorsally, laterally, and toward the head. The ventral surface of the laminae is concave from side to side. On the part which projects beyond the dorsal surface of the body are the **caudal articular surfaces**. These surfaces, also, are crescentic in outline and face ventrally and slightly toward the tail. Owing to the curve in the thoracic region of the vertebral column, the vertebrae caudal to the third or fourth are tilted so that the dorsal surfaces face more toward the head than when the bone is held with the ventral surface of the body horizontal.

The **neural canal** in the sixth thoracic vertebra is almost round.

#### CHARACTERS OF THE REMAINING THORACIC VERTEBRÆ.

Nearly all the different vertebrae present individual characters which enable them to be recognized, yet the fourth, fifth, sixth, and seventh are so much alike that it is difficult to identify them in a collection of vertebrae taken from different animals. If, however, these four vertebrae are taken from one skeleton, they may be distinguished by their relative size and by some minor characters.

The following are the peculiarities of the individual thoracic vertebrae:—

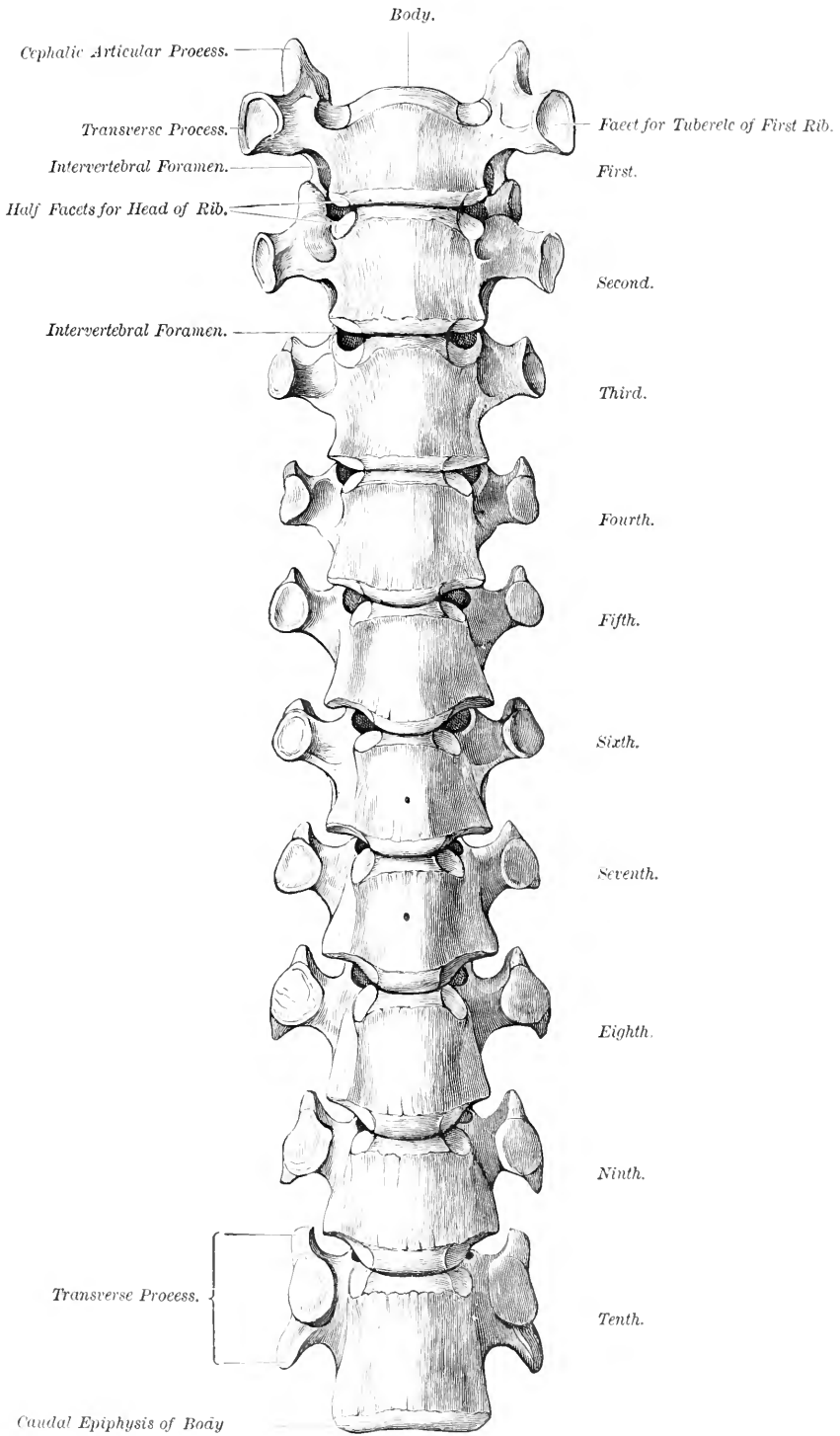
The **First Thoracic Vertebra** (Figs. 50, 51, 52).—The distinguishing characters of the first thoracic are the large and deeply cup-shaped costal articular facet on the ventral surface of the transverse process, and the entire facet on the cephalic end of the side of the body, for articulation with the head of the first rib.

The **transverse process** is prominent. It springs from the pedicle low down ventrally and slopes laterally and ventrally. Owing to the depth of the costal articular facet, the lateral surface of the process is reduced to a thin, arcuate border.

The **cephalic** and **caudal articular processes** are similar to the processes on the cervical vertebrae, and are distinct outgrowths from the arch. Each cephalic process appears to be a continuation toward the head, and dorsally and laterally, of the cephalic half of the dorsal end of the transverse process. Its articular surface faces equally dorsally and medially. Each caudal articular process is situated at

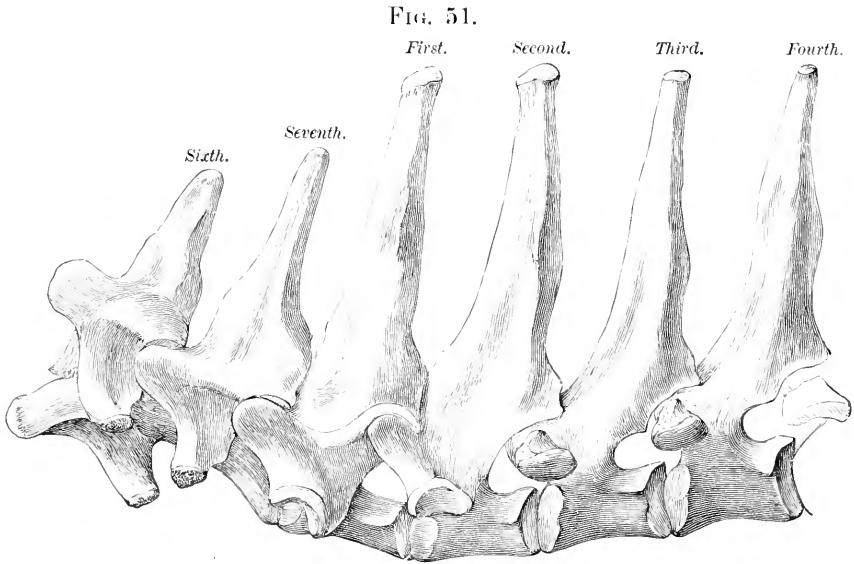


FIG. 50.



FIRST TEN THORACIC VERTEBRÆ, VENTRAL ASPECT.

the ventral caudal part of the side of the lamina, and is small, and projects dorsally and laterally. It is always in the ventral third of the maximum height of the vertebra when the ventral surface of the body is horizontal. The articular surface faces laterally, ventrally, and toward the tail. In no other of the long-spined cephalic thoracic vertebræ can the caudal articular surface be seen on the lateral aspect



THE SIXTH AND SEVENTH CERVICAL AND THE FIRST FOUR THORACIC VERTEBRÆ, SIDE VIEW.

of the bone. It shares with the second thoracic vertebra alone the distinct cephalic articular process, the ventrally directed transverse process, and the long distance between the lateral edge of the cephalic articular process and the tip of the transverse process.

The spinous process of the first thoracic is long, and usually is exceeded in length by the spinous process of the second alone. It points only slightly toward the tail.

The body resembles the bodies of the cervical vertebræ: it is flattened from the dorsal to the ventral side. The neural canal is higher than in any other thoracic vertebra, and its roof is more strongly arched.

The Second Thoracic Vertebra may be distinguished from the first in that, while possessing cephalic articular processes, it lacks distinct caudal articular processes. The cephalic articular surfaces, moreover, are not so widely separated, and encroach somewhat upon the cephalic edge of the laminae. It is distinguished from all caudal thereto by

its long spinous process, by the presence of cephalic articular processes, and by the long concave area on the dorsal surface of the transverse process lying between its tip and the cephalic articular process.

The side of the **body** has a costal half-facet at each end. The **transverse process** is not so large, and the area between its tip and the dorsal edge of the cephalic articular process is more sloping and less concave. The costal facet on its ventral surface is large, but smaller and shallower than that on the preceding vertebra.

The **pedicles** and **laminæ** have greater cephalo-caudal diameters.

The **spinous process** is usually longer than any other spinous process on the vertebral column. In the mounted skeleton it appears much higher, because the second vertebra itself is placed somewhat above the first.

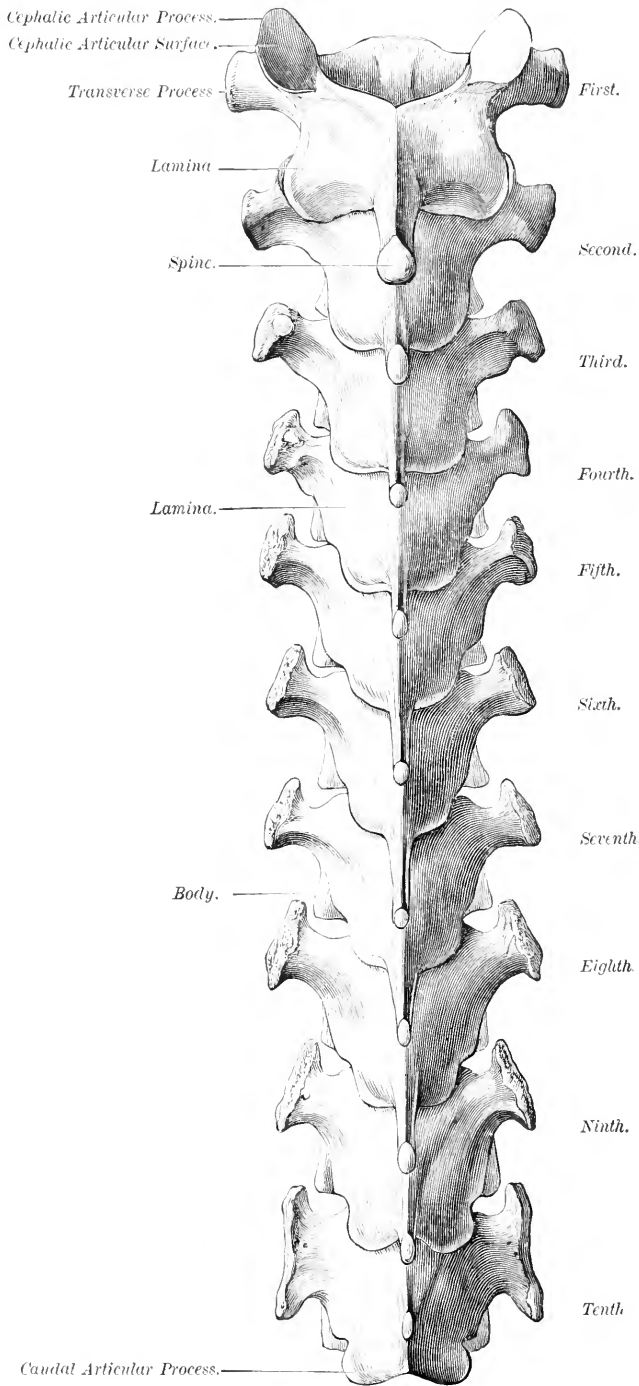
The **caudal articular surfaces** are in the ventral third of the maximum height measured on a line drawn perpendicular to the ventral surface of the body.

The **Third Thoracic Vertebra** (Figs. 50, 51, 52) differs from the second in possessing no distinct cephalic articular processes, the cephalic articulating surfaces appearing on the flattened, cephalic part of the dorsal surface of the laminæ. They therefore face dorsally, and are separated by a deep, triangular emargination in the edge of the laminæ, but are not so widely separated as the corresponding articular surfaces of the second vertebra.

The **transverse processes** are slightly shorter and their cephalo-caudal diameters greater than those of the second vertebra, and their origin is more dorsal on the pedicle. The **costal articular facet** is only slightly concave, and does not occupy the entire cephalo-caudal width of the ventral surface. The cephalic surface of the transverse process is narrow and depressed. On the dorsal surface is an oblong, elevated, flattened area which faces dorsally and laterally and corresponds with the surface described in the vertebrae which follow as the end or lateral surface of the process. The long diameter of this area is oblique, passing from the dorsal side ventrally and toward the tail. Caudal and medial to this area the dorsal surface is excavated and slopes ventrally and toward the tail, meeting the ventral surface at a sharp, emarginate, caudal edge.

The **laminæ** have a greater cephalo-caudal diameter and a narrower

FIG. 52.



THE FIRST TEN THORACIC VERTEBRÆ, DORSAL ASPECT.

transverse diameter at the caudal part than the laminae of the preceding vertebra.

The **spinous process** is more slender and somewhat shorter, and its inclination toward the tail is more marked.

There are no distinct caudal articular processes. The **caudal articular surfaces**, which face ventrally and slightly laterally, are in the ventral third of the maximum height of the vertebra, measured as before. The **neural canal** is slightly smaller.

The Thoracic Vertebrae from the fourth to the ninth, inclusive, are similar, and it is difficult to distinguish them in a collection of vertebrae taken from different animals; a strongly developed seventh, for example, may be similar in size and in the prominence of its processes to a sixth; or a seventh which is less developed may resemble an eighth. The difficulty is not great if we are studying the bones of one animal. In this case it will be observed that, as we pass from the third to the tenth, the following changes take place:

The **spinous processes** decrease in length and increase in inclination toward the tail. The **transverse processes** increase as to their cephalo-caudal diameters.

The median emargination in the cephalic border of the laminae becomes narrower.

The distance from the caudal articular surface to the tip of the spinous process, measured on the perpendicular to the ventral surface of the body, becomes gradually less, and the caudal articular surfaces apparently rise from the ventral third of the line to its middle point.

In the following description of the fourth, fifth, sixth, seventh, and eighth vertebrae, characters are given which will enable the student to recognize the vertebrae in any normal skeleton:

The **Fourth Thoracic Vertebra** (Figs. 50, 51, 52) is almost identical with the third. Two-thirds of its maximum height is dorsal to the caudal articular surfaces.

The **spinous process** is a little shorter. The caudal part of the laminae is somewhat narrower.

The lateral surface of the **transverse process** faces dorsally and laterally, and in form is still oblong, with the long diameter oblique. It is more convex and swollen, and its medial cephalic corner is often elevated into a decided tubercle. The cephalic surface of the trans-

verse process is larger. The neural canal is smaller, and the body has a somewhat greater dorso-ventral diameter.

The **Fifth Thoracic Vertebra** (Figs. 50, 52, 53) differs from the fourth in having less than two-thirds of its height dorsal to the caudal articular surfaces.

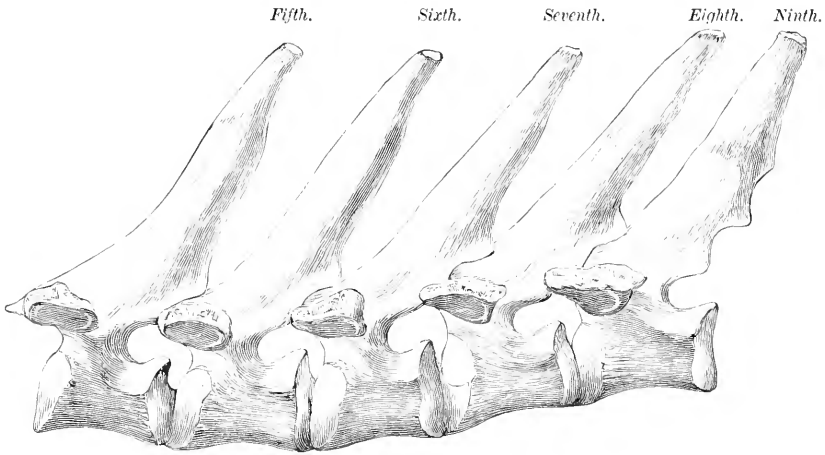
The spinous process may be slightly shorter.

The caudal part of the **laminæ** is narrower transversely, as is also the cephalic emargination. This can be tested by placing the cephalic edges of the two vertebræ together.

The cephalic and dorsal surfaces of the **transverse process** are larger, and the lateral surface, which is nearly square, faces more directly laterally.

The **Sixth Thoracic Vertebra** (Figs. 50, 52, 53) may be distinguished from the fifth by the transversely narrower caudal edge of the

FIG. 53.



THE FIFTH, SIXTH, SEVENTH, EIGHTH, AND NINTH THORACIC VERTEBRÆ, SIDE VIEW

**laminæ** and the narrower emargination on the cephalic edge. Three-fifths of the maximum height is dorsal to the caudal articular surfaces.

The **spinous process** is somewhat shorter, but has a more marked inclination toward the tail.

The lateral surface of the **transverse process** is quadrate, or slightly elongated in a cephalo-caudal line. It faces laterally and toward the head. The caudal intervertebral notch is slightly smaller.

\*The **Seventh Thoracic Vertebra** (Figs. 50, 52, 53).—The lateral surface of the **transverse process** is oblong, almost parallel with the

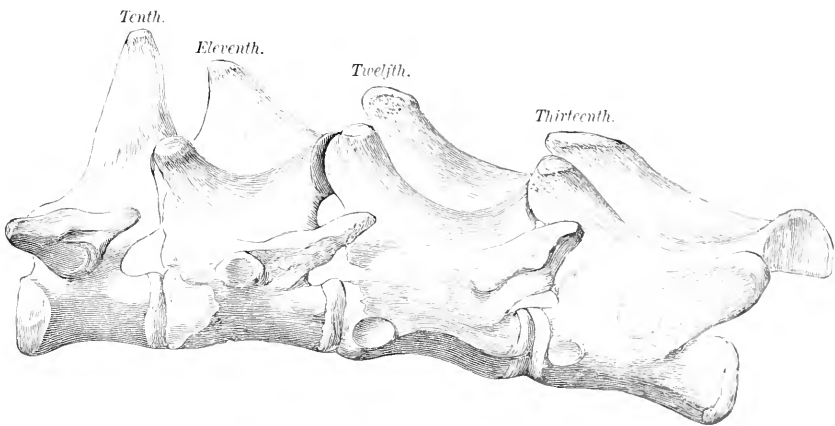
dorsal surface of the body, and the long axis is cephalo-caudal. About four-sevenths of the height of the vertebra is dorsal to the caudal articular surfaces.

The cephalic emargination of the *laminæ* is narrower than on the sixth vertebra. The cephalo-caudal diameter of the body, however, is somewhat greater.

In size and inclination the spinous process differs but little from the preceding vertebra.

The **Eighth Thoracic Vertebra** (Figs. 50, 52, 53).—The oblong lateral surface of the transverse process is still further elongated in its

FIG. 54.



THE TENTH, ELEVENTH, TWELFTH, AND THIRTEENTH THORACIC VERTEBRÆ, SIDE VIEW.

cephalo-caudal diameter, and its cephalic and caudal ends have hook-like projections. It faces less toward the head and more directly laterally.

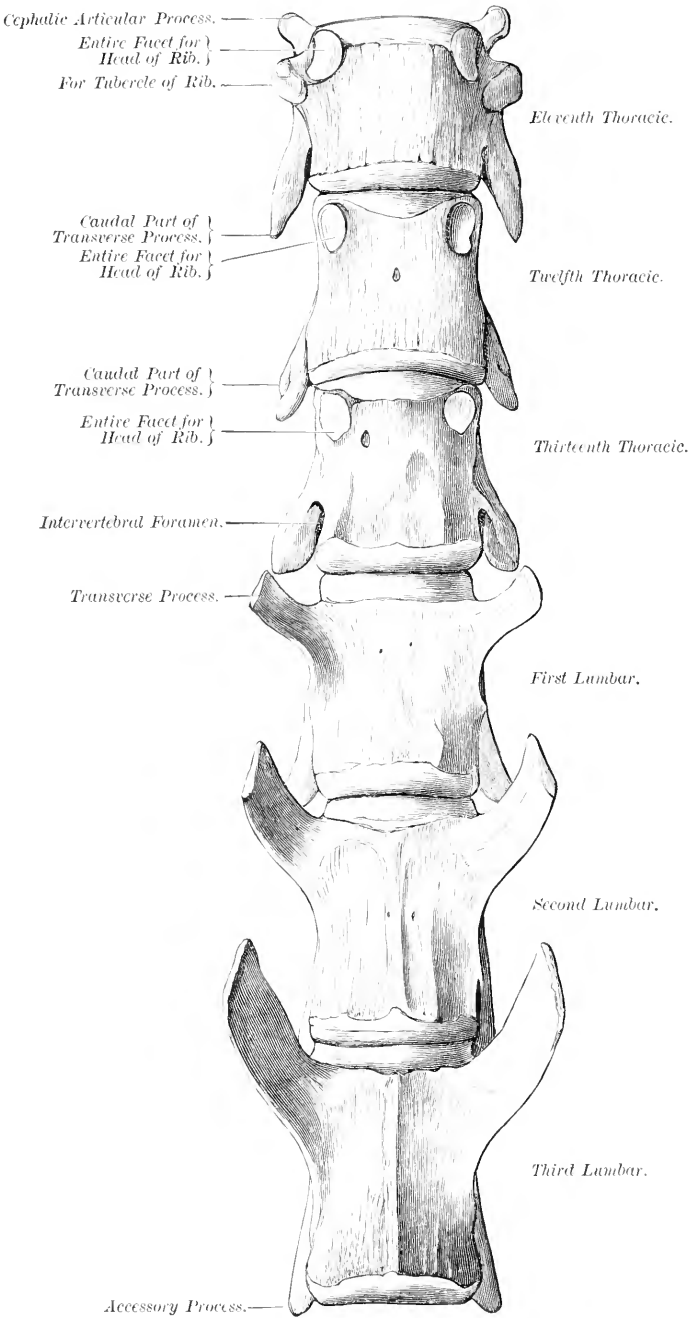
The spinous process is somewhat shorter, but its inclination toward the tail is so great that only a little more than half of the height of the vertebra lies dorsal to the caudal articular surfaces.

The cephalic laminar emargination is smaller, as is the caudal intervertebral notch.

The **Ninth Thoracic Vertebra** (Figs. 50, 52, 53) is not difficult to recognize. With the exception of the tenth, its spinous process is the **shortest** of all those which are inclined toward the tail. It may be distinguished from the tenth by the absence of the distinct caudal articular processes. Fully half its height lies dorsal to the posterior articular surfaces.

The lateral end of the transverse process is still further elongated,

FIG. 55.



LAST THREE THORACIC AND FIRST THREE LUMBAR VERTEBRÆ,  
VENTRAL ASPECT.



and presents a strong, rounded, cephalic tuberosity and a long, pointed, caudal spine.

The **Tenth Thoracic Vertebra** (Figs. 50, 52, 54) differs from all the thoracics so far considered, except the first, in having **distinct caudal articular processes** whereof the articular surfaces face laterally as well as ventrally and thus become visible when the bone is viewed from the side. Only a fourth of the height of the vertebra lies dorsal to the caudal articular surfaces.

The **spinous process** is very short, and has a less inclination toward the tail than the spinous process of the ninth vertebra.

This is the last thoracic vertebra possessing true **transverse processes** which articulate with the ribs. They are very different, however, from the transverse processes of the preceding vertebrae. Each is greatly elongated from head to tail, and its end bears distinct cephalic and caudal processes which are separated by a more or less well-defined dorso-ventral depression. These secondary processes are known as the **mammillary**<sup>1</sup> and **accessory**<sup>2</sup> processes. The mammillary is the cephalic process, and is smaller and more rounded. The accessory is the caudal process, and is longer and more pointed. The costal facet on the ventral surface of the transverse process is borne on a distinct elevation, and faces ventrally and laterally and toward the head. The **body** is more massive, and the **neural canal** is wider.

The **Eleventh Thoracic Vertebra** (Figs. 54, 55, 56) is known at once by its very small **triangular spinous process**, which points directly dorsally. This process marks the point where a change in the direction of the spinous processes takes place; the spinous processes of the remaining thoracic and of all the lumbar vertebrae point toward the head. The eleventh thoracic is therefore known as the **anticlinal**<sup>3</sup> vertebra, a term borrowed from geology, in which it is used to denote the line from which strata dip in opposite directions.

This vertebra has distinct **cephalic articular processes**, whereof the articular surfaces face dorsally and medially.

The **mammillary process** has a more dorsal origin, and now springs from the lateral side of the cephalic articular process. The **accessory process** is all that is left of the transverse process. It springs from

<sup>1</sup> From *mamma*, the breast, teat-like.

<sup>2</sup> From *accessum*, added.

<sup>3</sup> From (Gr.) *anti*, against, and *kline*, to lean.

the caudal half of the ventral part of the pedicle and is long and pointed, and projects toward the tail, dorsally and but slightly laterally.

The **caudal articular processes** are large and distinct, and their articular surfaces face almost directly laterally. Between the caudal articular process dorsally, the accessory process ventrally, and the pedicle on the cephalic side, is a large semicircular emargination which receives the cephalic articular process and the mammillary process of the twelfth vertebra, and thus increases the strength of the intervertebral articulation.

The **transverse process**, as such, is absent, and the rib articulates only by its head with an entire round facet on the cephalic end of the side of the body.

The **pedicles** have greater cephalo-caudal and dorso-ventral diameters and are directed more nearly perpendicular to the dorsal surface of the body. In a cross-section of the vertebra the **neural canal** has a rectangular outline.

The **body** is longer and wider than the body of the tenth vertebra.

The **Twelfth Thoracic Vertebra** (Figs. 54, 55, 56) differs from the eleventh by its greater size and by the shape and the cephalic inclination of the spinous process. The maximum cephalo-caudal length of this vertebra is about equal to the maximum dorso-ventral height.

Its **body** is about as wide as the body of the eleventh vertebra, and longer. The costal facet is more caudal.

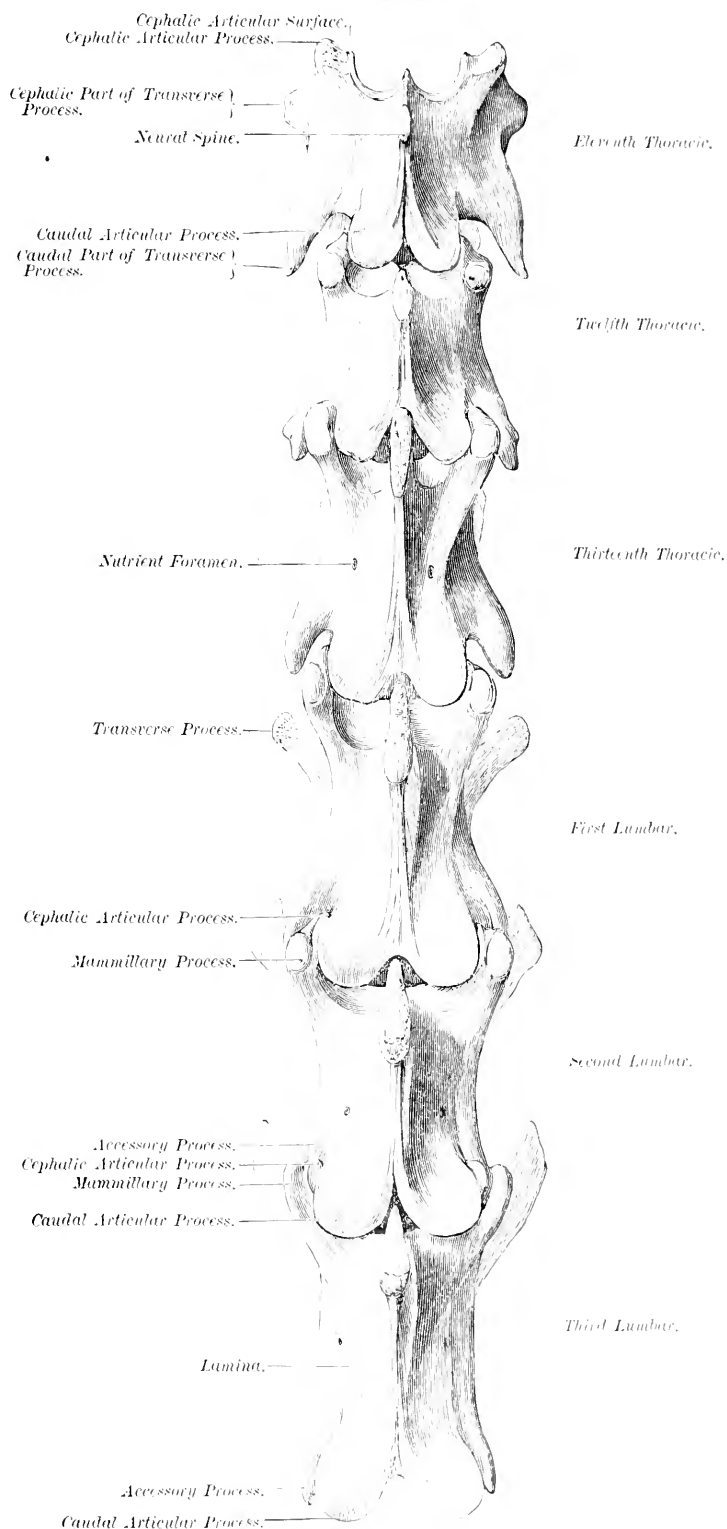
The **mammillary processes** and the **cephalic articular processes** are larger and longer, and the articular surfaces, which are concave in a dorso-ventral direction, are partly on the laminae, where they face dorsally, but principally on the processes, where they face medially.

The **accessory processes** are stouter, and project as far toward the tail as do the caudal articular processes. The gap between the caudal articular process, the pedicle, and the accessory process is smaller.

The **spinous process** occupies the greater part of the median line of the laminae, and, inclining toward the head and dorsally, rises considerably above the level of the mammillary processes. It is laterally compressed, and its cephalo-caudal diameter is less at the end than it is at the base. The cephalic and caudal borders are slightly emarginate, and, above the base, are almost parallel. The end presents a straight, or slightly arcuate, dorsal border.

The **Thirteenth or last Thoracic Vertebra** (Figs. 54, 55, 56) is

FIG. 56.



LAST THREE THORACIC AND FIRST THREE LUMBAR VERTEBRÆ,  
 DORSAL ASPECT.

distinguished from the preceding and from all the others by its much greater maximum cephalo-caudal length, which exceeds by a fourth, at least, its maximum dorso-ventral height. This increased length is due partly to the increase in the length of the body, but mainly to the greater cephalo-caudal length of the entire arch, and especially to the prolongation toward the tail of the caudal articular processes beyond the accessory processes.

The processes arising from the neural arch are all stouter. The **spinous process** is shorter, and has a greater inclination toward the head. The caudal intervertebral notch is larger.

#### RECAPITULATION OF CHARACTERS OF THORACIC VERTEBRÆ.

The vertebra with the greatest dorso-ventral height is the second, from which the others decrease in the following order: the first; then from the third to the tenth, inclusive; then the thirteenth, the twelfth, and the eleventh. In transverse width they decrease from the first toward the tail. The eighth has the greatest total cephalo-caudal length and the first the least.

The **bodies** do not vary much in size nor in shape, but the body of the sixth is slightly smaller than that of any other. With this exception, their cephalo-caudal diameters remain the same as far as the ninth, from which point this diameter gradually, but slightly, increases.

The transverse diameters are scarcely greater in the vertebræ nearest the tail than in those nearest the head. The dorso-ventral diameters in the first three or four vertebræ, however, are less than in those which succeed them. The **ventral surface** of the first three and the last two or three is less convex from side to side. The **sides** have cephalic and caudal half-facets for the ribs in all except the eleventh, twelfth, and thirteenth, which have single, complete cephalic facets. The cephalic facet of the first vertebra is almost complete.

The **neural arches**, and therefore the **neural canals**, are highest in the first three vertebræ. They are longest, in the cephalo-caudal line, in the twelfth and thirteenth. They are widest in the first two vertebræ and narrowest in the middle vertebræ. The **pedicles** increase in cephalo-caudal diameter from the first to the last.

The **transverse processes** are present in the first ten. Their origin on the arch gradually assumes a more dorsal position from the

first vertebra to the vertebræ nearer the tail. Their length diminishes from the first to the last. The cephalo-caudal diameter is least in the second; in the first and third about equal, but beyond the third it gradually increases to the tenth, inclusive. The lateral edges in the first and second are nearly parallel with the median plane; in the others, directed obliquely from the cephalic end laterally and toward the tail. Cephalic and caudal tubercles begin to appear at the third or fourth, and become on the tenth the rudiments of the **mammillary** and **accessory processes**, which are well developed on the last three vertebræ.

**Cephalic articular processes** are distinct in the first, the second, the eleventh, the twelfth, and the thirteenth. In these vertebræ the **cephalic articular surfaces** face dorsally and medially; in all the others they face dorsally.

The **caudal articular processes** are distinct on the first and on the last four. The **caudal articular surfaces** on these vertebræ face ventrally and laterally; on all the rest they face ventrally.

The distance from the ventral surface of the body to the caudal edge of the caudal articular surface, measured on a line vertical to the plane of the ventral surface of the body, is constant throughout the series, but the distance between the edge of the articular surface and the end of the spinous process becomes gradually less as we pass from the cephalic vertebræ to those which are more caudal. This is due to an actual decrease in the length of the spinous processes, and also to their increasing inclination toward the tail.

The following table will aid in distinguishing the different thoracic vertebræ; the numbers refer to the vertebræ:

TABLE.

Transverse processes present, articulating with ribs.

Cephalic articular processes distinct; project dorsally and laterally.

Caudal articular processes distinct; articular surfaces face also laterally . . . . . 1

Caudal articular processes not distinct; articular surfaces face ventrally . . . . . 2

Cephalic articular processes not distinct from laminae.

Caudal articular processes not distinct.

    Lateral aspect of transverse process obliquely elongated ; it faces also dorsally.

        Spinous process longer . . . . . 3

        Spinous process shorter . . . . . 4

    Lateral aspect of transverse process usually quadrate ; it faces slightly dorsally.

        Vertebra not distinctly smaller . . . . . 5

        Vertebra distinctly smaller . . . . . 6

    Lateral aspect of transverse process faces laterally and its cephalo-caudal diameter progressively prolonged.

        Spinous processes progressively decrease in length and increase in inclination toward the tail . . . . . 7, 8, 9

Caudal articular processes distinct ; articular surfaces face also laterally . . . . . 10

Transverse processes absent ; mammillary and accessory processes present ; single costal facet on body.

    Spinous process small ; it points dorsally . . . . . 11

    Spinous process larger ; it points toward the head.

        Maximum length of whole vertebra not greater than height . . . . . 12

        Maximum length of whole vertebra greater than height . 13

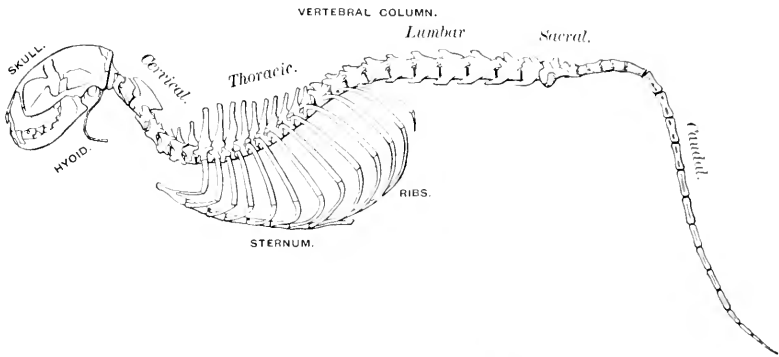
THE LUMBAR VERTEBRÆ.

The Seven Lumbar Vertebrae are situated between the thoracic vertebrae and the sacrum (Fig. 57), supporting that portion of the body known as the loins.

The Lumbar Vertebrae (Fig. 58) differ from the cervicals in the absence of an arterial foramen in the transverse process. They differ from the thoracics in the absence of the facets for the ribs. They differ from the caudal vertebrae in having large spinous processes and transverse processes which are directed toward the head and ventrally. They may be distinguished from the seventh cervical, which has no arterial foramen in the transverse process, by their elongated, massive form, and by the cephalic direction of the spinous and transverse processes. They all have mammillary processes on the cephalic

articular processes, and all except the last have accessory processes. The transverse process springs from the cephalic part of the lateral

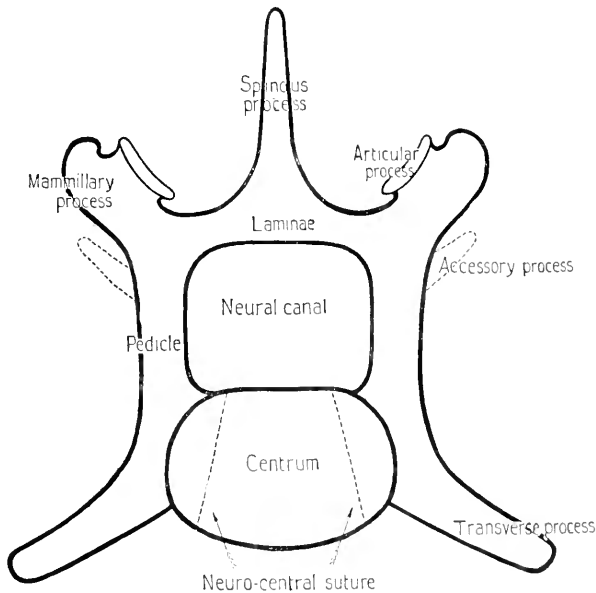
FIG. 57.



THE AXIAL SKELETON. (Greatly reduced.)

surface of the body, never from the pedicle or lamina, and occupies on the lumbar vertebrae the position occupied by the dorsal end of

FIG. 58.

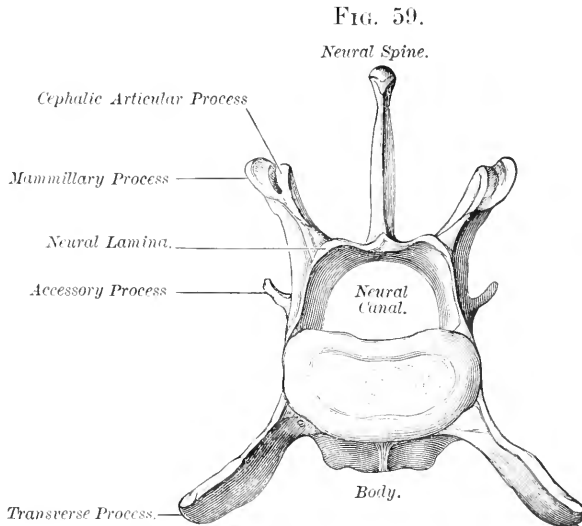


PLAN OF A LUMBAR VERTEBRA. END VIEW.

the rib on the thoracic vertebrae. It is always directed toward the head. The general form of the lumbar vertebrae has been anticipated in the last three thoracics.

A TYPICAL LUMBAR VERTEBRA.

The **Fourth Lumbar Vertebra**.—The body is six-sided, with greater cephalo-caudal than transverse diameter; it is flattened in a dorso-ventral line, so that the height is not more than half the width. The flat dorsal and ventral surfaces are parallel, as are the smaller lateral surfaces. The cephalic and caudal surfaces are similar. They are almost rectangular, with the transverse width twice as great as the dorso-ventral height (Fig. 59).



A LUMBAR VERTEBRA, ANTERIOR OR CEPHALIC ASPECT.

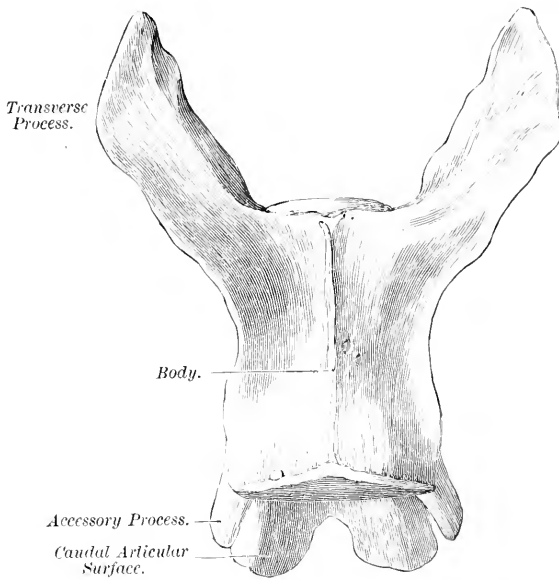
The **transverse processes** are thin plates which have their origin on the cephalic half of the edge between the ventral and lateral surfaces, and are directed ventrally, laterally, and toward the head. They present cephalic, caudal, and lateral edges, and dorsal and ventral surfaces. Their cephalic and caudal edges are almost parallel. They are slightly sinuate, but the cephalic edge is more or less emarginate, the caudal more or less arcuate. The end is cut off obliquely, so that the lateral margin is directed from the caudal end medially and toward the head, forming a sharp acute angle with the cephalic edge and an obtuse, sometimes indefinite, angle with the caudal edge. The dorsal and ventral surfaces are, in the main, flat, with their cephalo-caudal diameter equal to half the transverse diameter.

The ventral surface (Fig. 60) is faintly convex in a cephalo-caudal direction, and is sometimes ridged for muscular attachment. It faces ventrally and toward the middle line.



The dorsal surface (Fig. 61) is usually slightly concave in a cephalo-caudal direction, and sometimes is even excavated. Its ventral

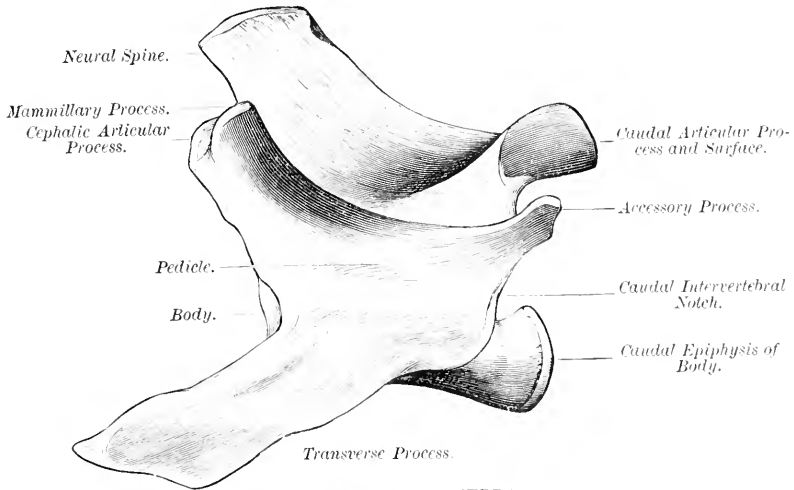
FIG. 60.



A LUMBAR VERTEBRA, VENTRAL ASPECT.

part is so twisted outward on itself that it faces more dorsally than does the dorsal part. The general direction of the surface is dorsal and lateral.

FIG. 61.



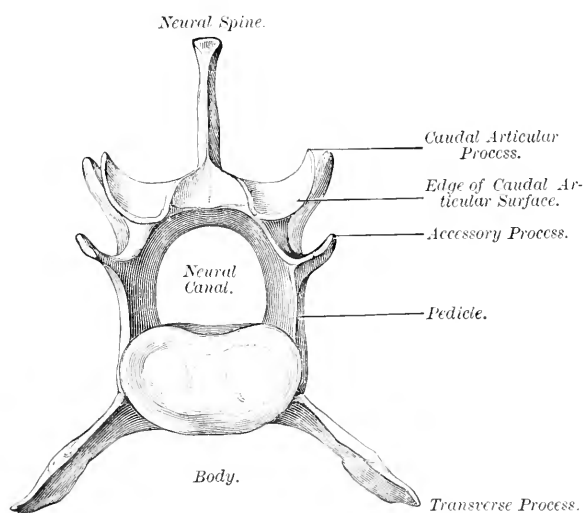
A LUMBAR VERTEBRA.

The pedicles have long cephalo-caudal and dorso-ventral diameters and are parallel with each other. The former diameter almost equals

that of the body, thus forming only a small caudal intervertebral notch. Near the dorsal part of the caudal half of the lateral surface is the pointed **accessory process**, which is directed dorsally and toward the tail. It has a small dorsal surface which faces dorsally and medially, and a larger ventral surface, continuous with the lateral surface of the pedicle, which faces ventrally and laterally. The base of the accessory process is connected by a faint ridge with the base of the cephalic articular and mammillary processes.

The **laminæ** (Fig. 64) have a cephalo-caudal diameter equal to that of the body. They are almost flat at the cephalic end, but slope dorsally at the caudal end, and are produced into the caudal articular processes.

FIG. 62.

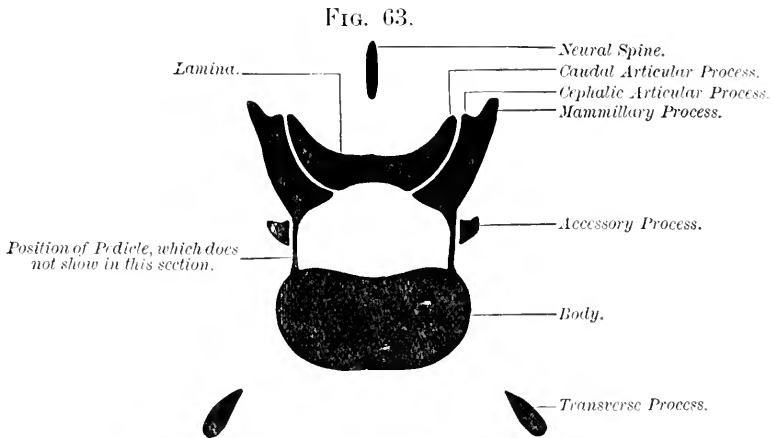


A LUMBAR VERTEBRA, POSTERIOR OR CAUDAL ASPECT.

Each of the **caudal articular processes** (Fig. 62) is semicircular, and its dorsal surface is strongly concave from side to side and less strongly convex from the cephalic to the caudal end. The **articular surface** is flat in the cephalo-caudal line, strongly convex from side to side, and faces ventrally and laterally. Its cephalic part is separated from the tip of the accessory process by a notch, which receives the cephalic articular and mammillary processes of the fifth vertebra. The two caudal articular processes are separated by a longitudinal incision.

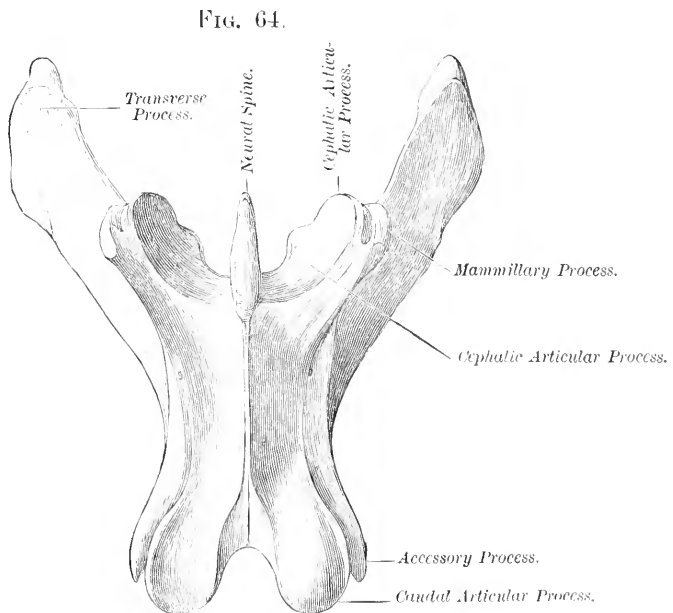
The **cephalic articular process** rises boldly dorsally and slightly laterally and toward the head, from the cephalic part of the edge

between the lamina and the pedicle. The **mammillary process** is the rounded tubercle on the lateral side of the tip, and separated from



TRANSVERSE VERTICAL SECTION THROUGH AN INTERVERTEBRAL JOINT IN THE LUMBAR REGION.

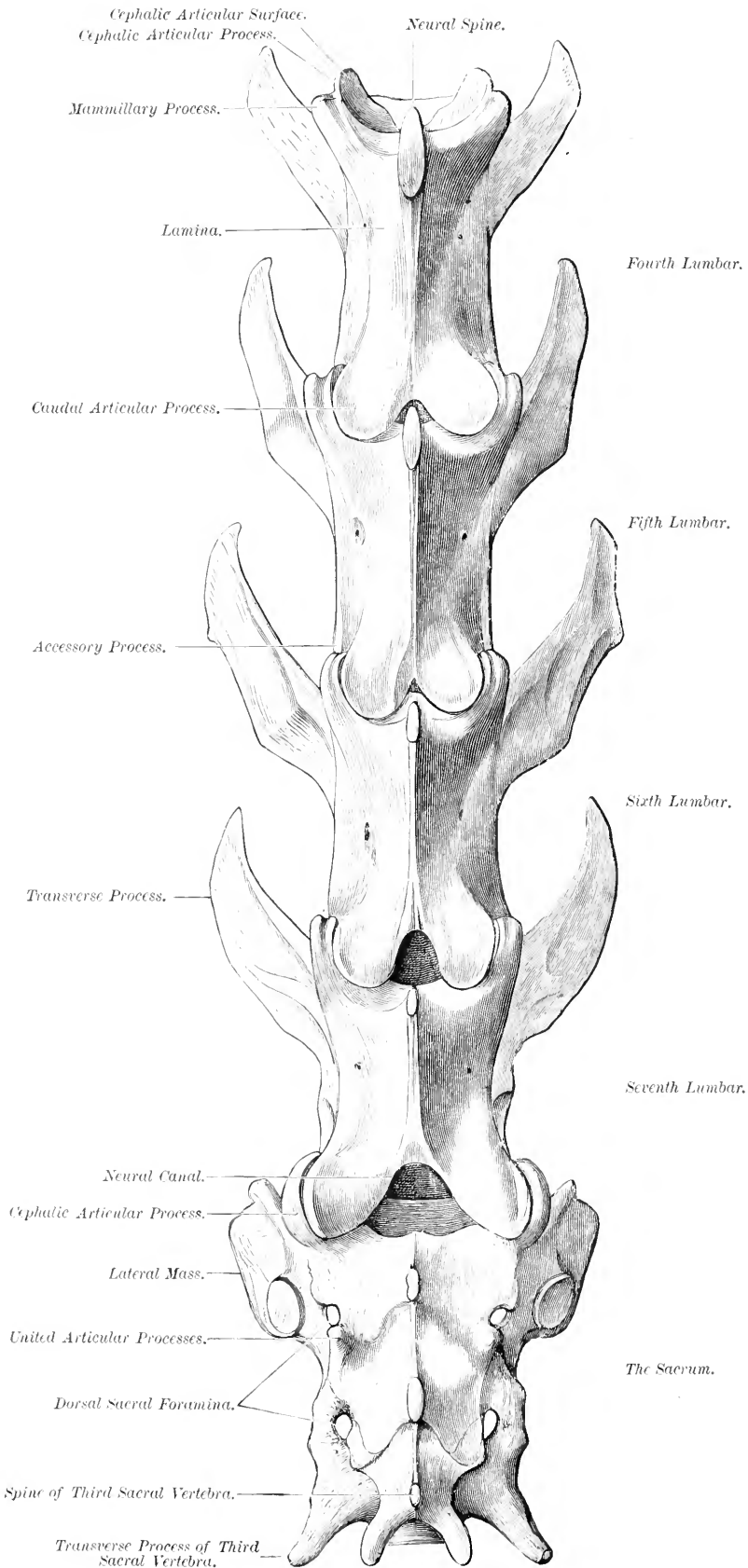
the sharp dorsal edge of the cephalic articular surface by a groove. The articular process has a slightly emarginate caudal edge directed dorsally and toward the tail, and a sinuate cephalic edge which is



A LUMBAR VERTEBRA, DORSAL ASPECT.

almost vertical. The quadrate lateral surface is concave in the dorso-ventral direction and convex in the cephalo-caudal direction; and faces

FIG. 65.



LAST FOUR LUMBAR VERTEBRÆ AND SACRUM, DORSAL ASPECT.

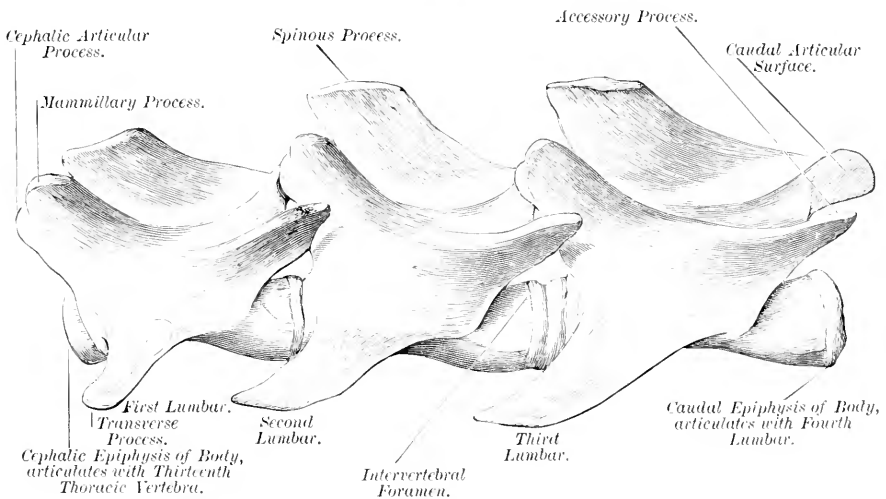
laterally, ventrally, and slightly toward the head. Its caudal-dorsal angle is produced into the mammillary process. The medial surface, except for a small area near the base, is entirely occupied by the **cephalic articular surface**, which is continued medially on the cephalic part of the lamina. Each articular surface is circular, concave from the dorsal to the ventral edge, and faces medially and dorsally. The two cephalic articular processes are separated by a deep emargination on the cephalic edge of the laminae.

The **spinous process** rises from the entire length of the neural arch. It is thin and wedge-shaped. Its caudal edge is directed as much toward the head as dorsally; its cephalic edge is more nearly vertical. The dorsal edge is short and slightly arcuate.

The **neural canal** is almost square in cross-sections.

The lumbar vertebrae are so much alike that they can be distinguished from one another only by their size and by the degree of development of some of their processes (Figs. 65, 66, 67, 68, 69).

FIG. 66.



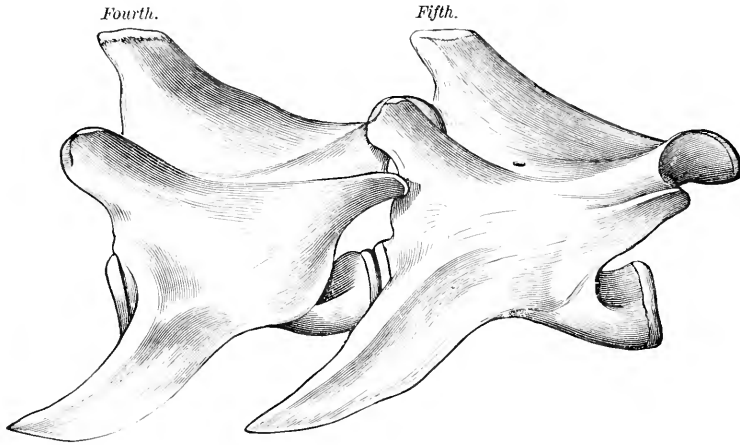
FIRST THREE LUMBAR VERTEBRÆ, LEFT SIDE.

The lumbar vertebrae nearest the head resemble those thoracic vertebrae nearest the tail in which the change from the thoracic type to the lumbar type has already taken place; indeed, except for the presence of transverse processes and for the absence of ribs, any one of the lumbar might be mistaken for a large twelfth or thirteenth thoracic.

The change from the lumbar type to the caudal type takes place mainly in those elements which coalesce to form the sacrum.

For these reasons there is a uniformity throughout the series of lumbar vertebræ such as obtains in no other group,—a uniformity which renders it extremely difficult to recognize the different members

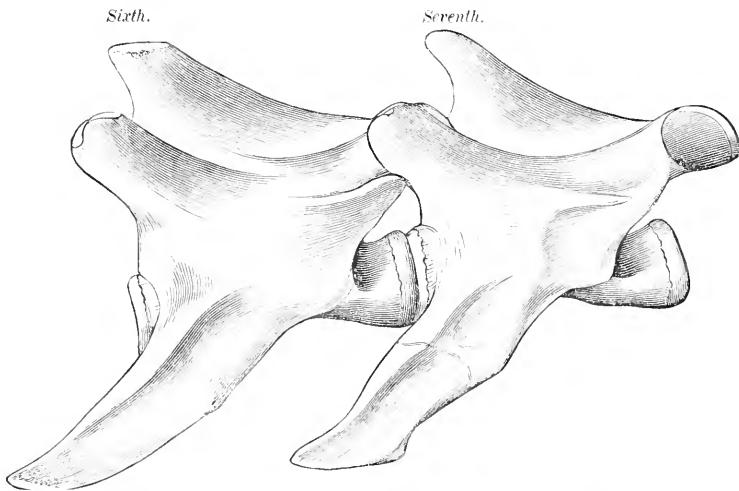
FIG. 67.



THE FOURTH AND FIFTH LUMBAR VERTEBRÆ.

of the series in a collection of vertebræ derived from animals of all ages and degrees of muscular development. The task is much easier when the lumbar vertebræ of one skeleton are studied.

FIG. 68.

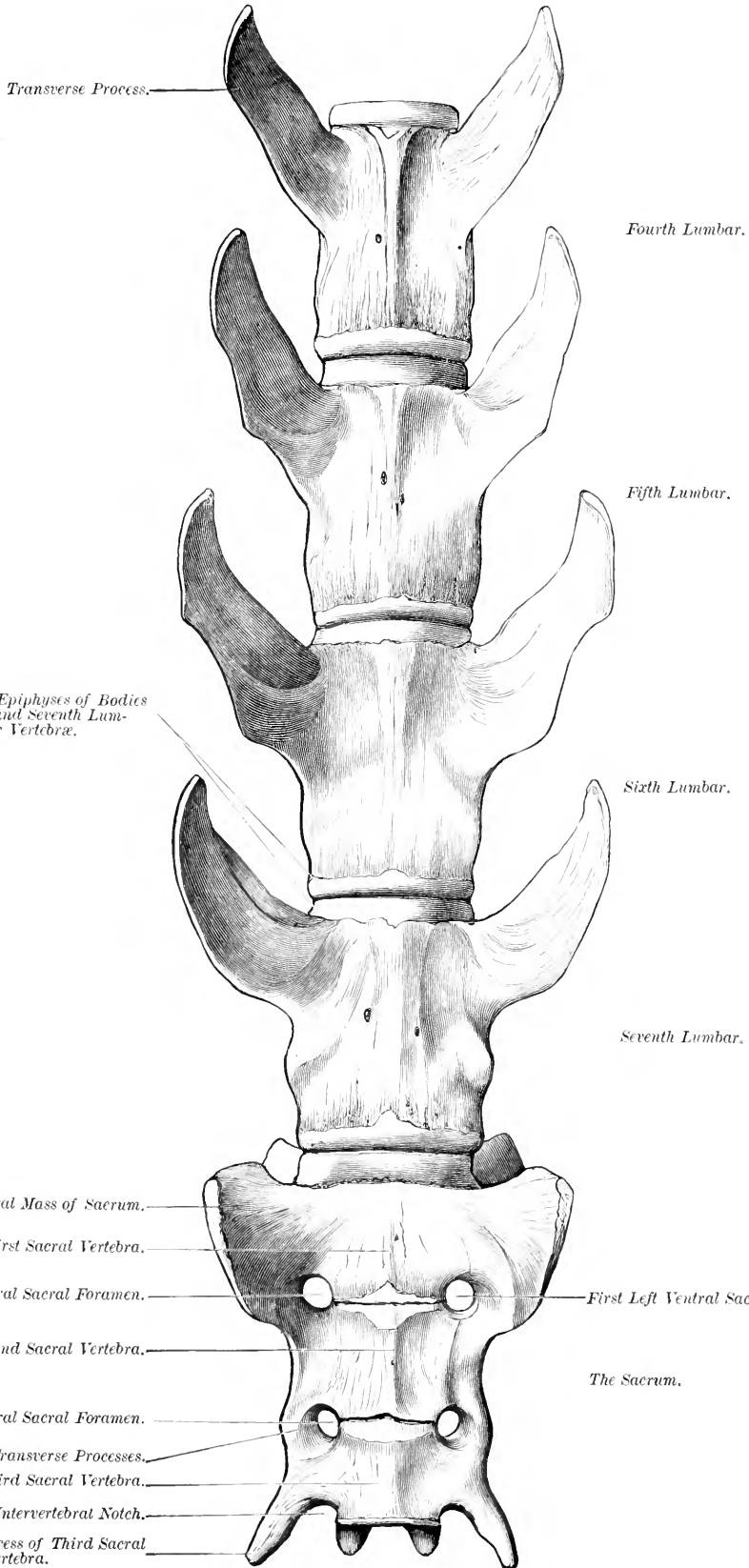


THE SIXTH AND SEVENTH LUMBAR VERTEBRÆ.

In either case, however, the following differences will be observed :

The bodies and the neural arches increase in size from the first to the fifth ; in the seventh they are much shorter.

FIG. 69.



LAST FOUR LUMBAR VERTEBRÆ AND SACRUM, VENTRAL ASPECT.

The **neural canal** increases very slightly in width and height from the first to the last.

The **transverse processes** are very short and straight in the first; then they increase in length and curvature. In the first three or four vertebræ the end is cut off squarely; in the rest it is narrowed to a point. In the vertebræ near the tail, usually beginning with the fifth, the caudal edge of the transverse process may present a decided angle, and its dorsal surface may be more strongly marked by ridges for muscular attachment.

The **accessory processes** are probably the most trustworthy of all the distinguishing characters. They are longest and strongest in the first, and then regularly diminish, until they become rudimentary on the sixth and disappear on the seventh. Sometimes they are rudimentary on the fifth and wanting on the sixth.

The **mammillary processes** likewise decrease in size in the same order, but, as they are less prominent, the character is hardly as trustworthy.

The **spinous processes** increase in length from the first to the last, and increase in cephalo-caudal diameter to the fourth; beyond this they become more pointed.

The **articular processes** present no important changes in form, but the caudal articular processes of the seventh lumbar are so large and so widely separated that they form a constant character for the recognition of that vertebra.

### THE SACRAL VERTEBRÆ.

The three vertebræ which follow the seventh lumbar (Fig. 70) are known as the **false vertebræ**; they have lost their individuality by coalescence. The single bone thus formed, called the Sacrum, is joined at parts of its lateral surfaces to the hip-bones, completing the **pelvic girdle**, and forming part of the dorsal bony wall of the pelvis.

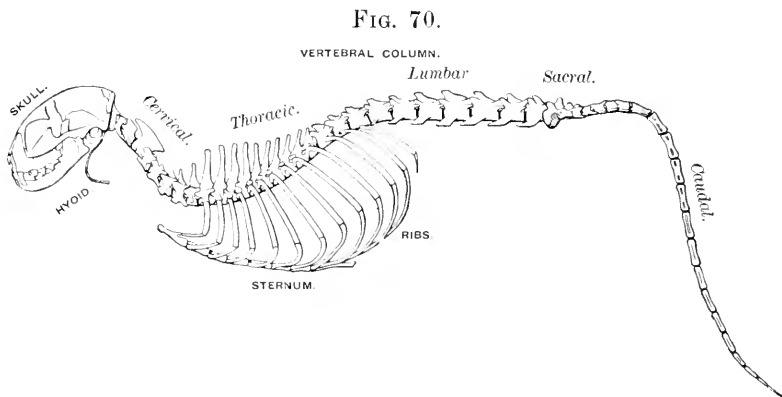
That the sacrum is composed of three vertebræ is always apparent. In young specimens they may be readily broken apart at the places of coalescence, which even in old specimens are plainly visible. The union of the vertebræ takes place at four points, and involves four parts of the contiguous vertebræ:

(1) The **ends of the bodies** are joined together by the ossification of the intervertebral cartilages; of course, by the union of the caudal



end of the body of the first vertebra with the cephalic end of the body of the second, and of the caudal end of the body of the second with the cephalic end of the body of the third. The cephalic end of the body of the first sacral vertebra articulates with the caudal end of the last lumbar, and the caudal end of the body of the third sacral articulates with the cephalic end of the first tail vertebra.

(2) The **cephalic and caudal articular processes** become firmly united, forming on the dorsal surface of the sacrum four tubercles,—



two on each side. Each of the cephalic pair represents the caudal process of the first vertebra and the cephalic process of the second, and each of the caudal pair represents the caudal process of the second and the cephalic process of the third. The cephalic articular processes of the first and the caudal articular processes of the third are free, and become the cephalic and caudal processes of the sacrum, articulating with the caudal and cephalic articular processes of the last lumbar and first tail vertebra, respectively.

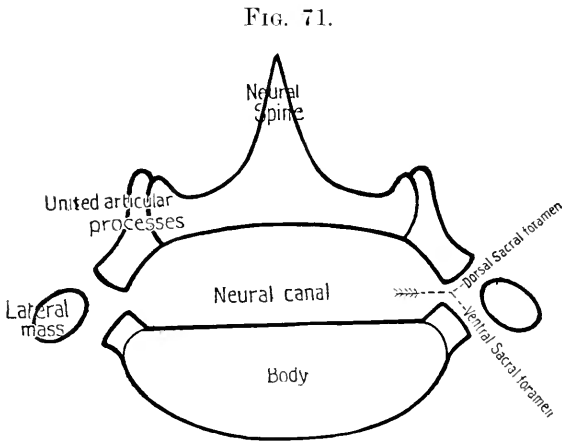
(3) The third union which takes place in the sacral vertebrae is between contiguous edges of the *laminæ*.

(4) The fourth and most characteristic change affects the **transverse processes** of all three vertebrae, which on each side are all joined together into a common continuous mass. Those of the first vertebrae are developed into large **lateral masses**, whereof the cephalo-caudal and dorso-ventral diameters are much greater than those diameters of the body of the vertebra. The transverse processes of the second vertebra are low, but are prolonged in a cephalic direction to join the lateral masses, and in a caudal direction to join the ends of the trans-

verse processes of the third vertebra. The caudal end of the transverse processes of the third vertebra project laterally and toward the tail, and are known as the **inferior angles**. This union of the transverse processes does not comprise their entire transverse width, but is confined to the lateral portion. There are thus produced two pairs of vertical

canals, which open on the dorsal and ventral surfaces by the **dorsal and ventral sacral foramina** (Fig. 71).

Each of these canals has its lateral-cephalic, its lateral, and its caudal walls formed of the contiguous transverse processes; but its medial-cephalic wall, which is dorsally formed of the laminae and ventrally of the bodies, is largely occupied by a foramen leading into the neural canal.



TRANSVERSE SECTION OF SACRUM THROUGH SACRAL FORAMINA (DIAGRAMMATIC).

This foramen is at once recognized as the **intervertebral foramen** of the other vertebrae. Each intervertebral foramen gives exit to a sacral spinal nerve whereof the dorsal and ventral branches leave the sacrum by the dorsal and ventral foramina respectively.

Inasmuch as in macerating the bones of a young skeleton the sacral vertebrae may be broken apart, it is important to note the characters whereby these vertebrae may be distinguished from all other vertebrae and from one another. They differ from all the cervicals, except the seventh, by the absence of the cephalo-caudal arterial canal; from the seventh, by their short spinous processes. They differ from the thoracics by the absence of facets for the attachment of the ribs, and from the lumbar by their dorso-ventrally compressed shape, by their comparatively small transverse processes, and by the absence of mammillary and accessory processes. They may be distinguished from the first vertebrae of the caudal region, since these have no spinous processes and have narrow, free transverse processes which point toward the tip of the tail. The last caudal vertebrae have entirely different and cylindrical forms.

The **First Sacral** differs from the two which follow by its superior size, by the large lateral masses, and by the very prominent cephalic articular processes.

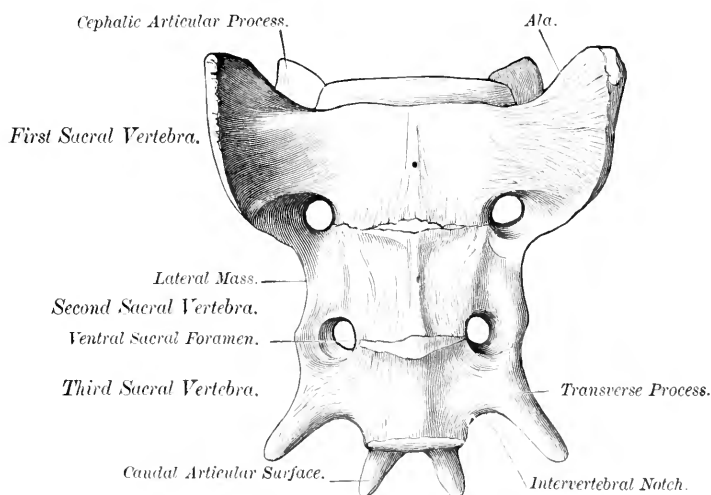
The **Second Sacral** differs from the third by its superior size and by showing the marks of bony union at each end.

The **Third Sacral** differs from the second and first by its inferior size and by the caudal and lateral direction of the caudal end of the transverse processes.

### THE SACRUM.

**General Description.**—The Sacrum is irregularly rectangular, wider and higher at the cephalic end than at the caudal end. Its cephalo-caudal diameter, which about equals the maximum cephalo-caudal diameter of the seventh lumbar vertebra, is an eighth greater than its greatest transverse width at the cephalic end. The maximum dorso-ventral height is a third less than the maximum cephalo-caudal

FIG. 72.



THE SACRUM, VENTRAL ASPECT.

diameter. In the ordinary position in walking, the cephalic end of the sacrum has a greater dorso-ventral diameter than the caudal end.

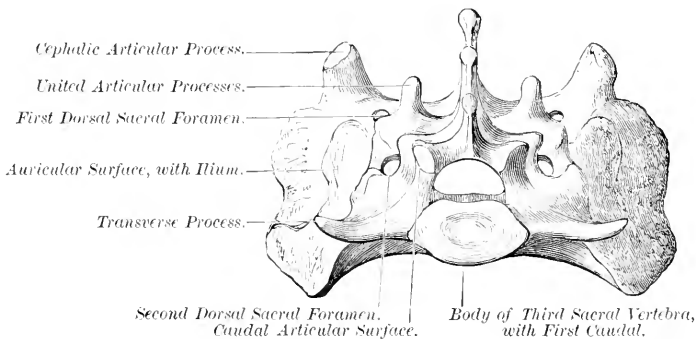
The outline of the **ventral surface** (Fig. 72) of the sacrum is rhomboidal. The cephalic third of the surface is twice as wide transversely as the caudal two-thirds, except where the caudal angles are produced laterally and toward the tail. Each lateral margin is, in its cephalic third, sharp, prominent, arcuate in a cephalo-caudal line, and

directed from the cephalic end toward the tail and the median line. Caudal to the cephalic third the margin is flat and emarginate, but opposite the second ventral sacral foramen it presents a swelling. The caudal border is straight and transverse in the middle, but deeply emarginate on each side.

The cephalic margin is likewise straight and transverse for most of its extent, but at each side it curves toward the head and laterally. The cephalic third of the ventral surface is strongly concave from side to side. The middle of the concavity is flattened, and is the **promontory**. On each side of this area the surface is convex in a cephalo-caudal line. In the caudal two-thirds the ventral surface is in general slightly concave in the same direction, except where it is convex at the region of junction of the vertebral bodies. It is convex from side to side in the middle line. On each side of this median convexity the ventral surface is flattened or slightly concave in the cephalic part and slightly convex in the caudal part.

The ventral surface is pierced by four **ventral sacral foramina**, which are arranged in two pairs, placed approximately at the junctions

FIG. 73.

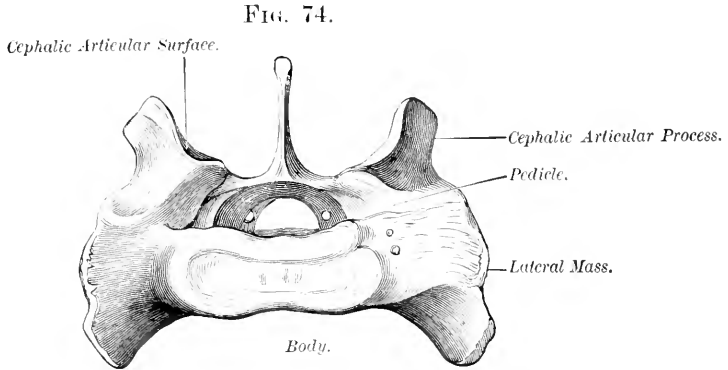


THE SACRUM, POSTERIOR OR CAUDAL VIEW.

of the end thirds with the middle third and a little nearer the lateral margin than the median line. They pierce the bone obliquely from the lateral side toward the cephalic end and the median line. The cephalic pair are circular and larger and placed further apart than the caudal pair, which are oval, with the long diameter of the oval directed obliquely from the median line laterally and toward the head.

The **caudal surface** (Fig. 73) comprises the middle caudal surface of the third sacral vertebra, and is transversely oval and continued on each as the thin, concave, caudal edge of the inferior sacral angle.

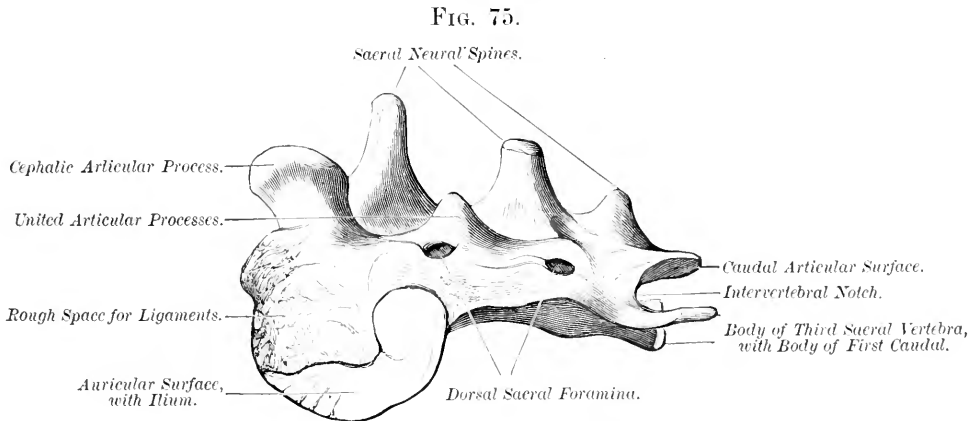
The **cephalic surface** (Fig. 74) is a third wider than the caudal surface and at least twice as high. Its middle is occupied mainly by the prominent, flat, and oblong surface which joins the body of the seventh lumbar. On each side of this surface is the triangular



THE SACRUM, ANTERIOR OR CEPHALIC VIEW.

cephalic surface of the lateral mass, convex from the dorsal to the ventral edge, and sloping laterally and toward the head.

Each lateral surface (Fig. 75) consists of two parts of nearly equal cephalo-caudal length. Of these, the **cephalic half** is the side of the lateral mass contributed by the transverse process of the first sacral vertebra. It is almost as high as it is long; pear-shaped, large at the



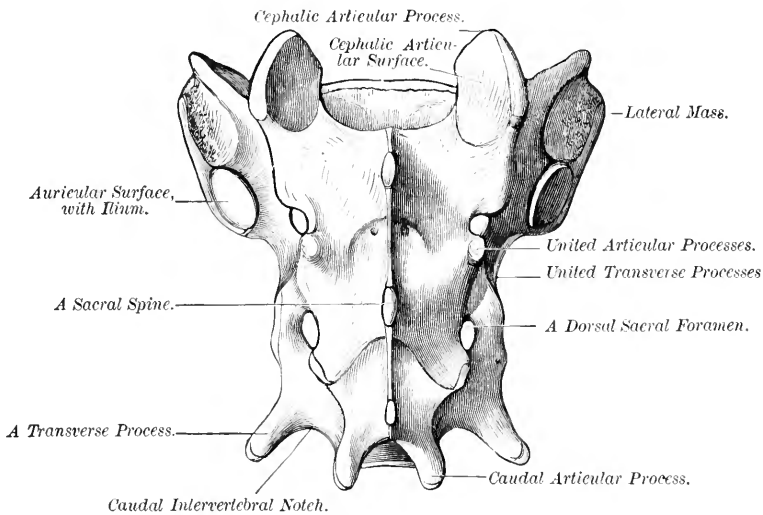
THE SACRUM, SIDE VIEW.

cephalic and narrow at the caudal part. Its arched ventral margin is sharp. Its dorsal margin is divided from the dorsal surface of the sacrum by an arcuate, elevated line, which is crossed obliquely from the caudal end, ventrally and toward the head, by a **groove**, leading from the first dorsal sacral foramen. The surface is, in general, flat,

and faces laterally, toward the tail, and slightly dorsally. An ear-shaped **auricular<sup>1</sup> articular facet**, which occupies its caudal and ventral half, joins a facet on the cephalic part of the inner surface of the innominate bone. The remainder of the surface, lying cephalic and dorsal to the auricular surface, is **excavated** and roughened, and furnishes attachment to strong sacro-iliac interosseous ligaments. The **caudal half** of the lateral surface is little more than a border limiting the dorsal and ventral surfaces of the united transverse processes. As a surface, it is straight in the cephalic part, but curves laterally as well as toward the tail.

The **dorsal surface** (Fig. 76) of the sacrum has the same general outline as the ventral surface, but is not so wide in the cephalic part.

FIG. 76.



THE SACRUM, DORSAL ASPECT.

It is composed of the dorsal surfaces of the united laminae and transverse processes of the constituent vertebrae.

The cephalic border presents a considerable median emargination, at each side of which are the prominent **cephalic articular processes**. Each process is directed laterally, dorsally, and toward the head beyond the lateral masses of the body. It is compressed from side to side, and is as high as it is long. Its lateral surface is convex from the cephalic to the caudal edge and concave in a dorso-ventral line, and forms, when the sacrum and the innominate are united, the

<sup>1</sup> From *auricula*, a little ear.

median wall of a deep notch. The **cephalic articular surface** occupies the medial surface of the articular process. It is very slightly concave dorso-ventrally, and faces toward the median line and the head, and dorsally. The cephalic border on each side of the articular process is sinuate; from the median line laterally, first emarginate, and then arcuate. It curves ventrally and toward the head into the upper part of the cephalic border of the lateral mass.

In the middle line of the dorsal surface are the three **sacral spinous processes**. They are, as a rule, distinct from one another, although occasionally their opposite edges may unite at their bases. They are triangular and laterally compressed and point dorsally. Their tips sometimes have a slight cephalic curve. Of the three, the first is the largest and the third the smallest.

On each side of the median line, opposite the intervals between the spinous processes, are the **tubercles** formed by the united articular processes. They vary much in size and in the degree of coalescence of their elements. Cephalic and lateral to each tubercle is a **dorsal sacral foramen**. These foramina are oval and of equal size, and placed, like the caudal ventral foramina, obliquely. A **groove**, more or less distinct, leads from the lateral end of each foramen in a cephalic and lateral direction.

The **caudal articular processes** or **sacral cornua** are small, but prominent and distinct. They are directed toward the tail and but slightly laterally and dorsally. They overhang the neural canal and also the caudal intervertebral notches, which are large. The caudal articular surfaces face ventrally and laterally.

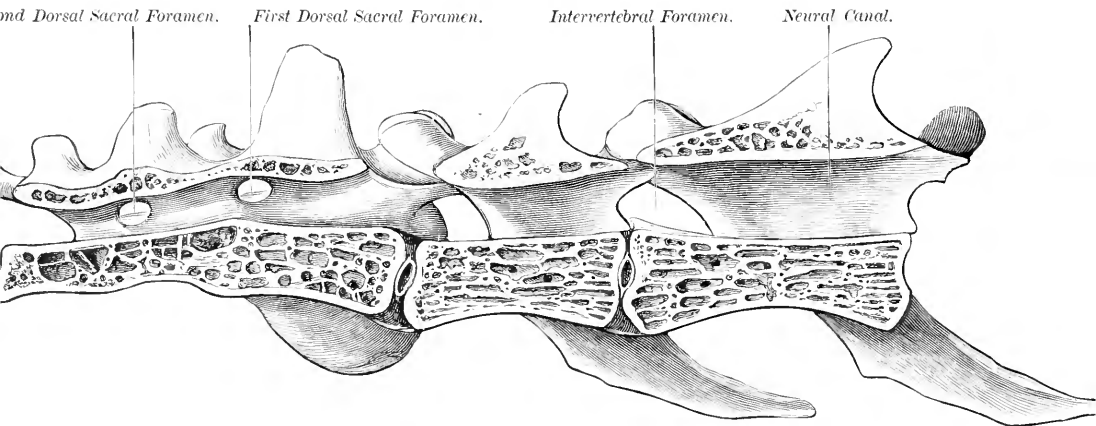
The lateral border of the dorsal surface is, in the cephalic part, the somewhat irregular dorsal border of the lateral surface of the lateral mass, caudal to which it is thin and emarginate. The caudal angles are produced laterally and toward the tail. The caudal margin of the dorsal surface is interrupted in the middle by the laminae carrying the articular processes, at each side of which, on a lower level, it forms the deeply emarginated caudal border of the inferior lateral angle.

The part of the dorsal surface included between the spinous processes and the line of free and coalesced articular processes is the laminar part of the sacrum, and forms a strip wider in the cephalic part than in the caudal part, and elevated above the rest of the dorsal surface. It is convex from the median line laterally, and nearly flat

from the cephalic to the caudal end, except where, at the lines of laminar coalescence, it is somewhat swollen. Lateral to the line of the articular processes, caudal to the lateral mass, the dorsal surface is a narrow strip which slopes ventrally and laterally.

The **neural canal** (Figs. 73, 74, 77) is low and wide. It is a third wider and a little higher at the cephalic end than it is at the caudal end. Its ventral wall, the dorsal surface of the body of the sacrum, is flat from side to side and slightly convex along the median line. Its

FIG. 77.



LONGITUDINAL VERTICAL SECTION THROUGH SIXTH AND SEVENTH LUMBAR VERTEBRÆ AND THE SACRUM.

roof is flattened at the cephalic end, but is more arched at the caudal end. The lateral walls terminate, at each end, at the intervertebral notches, and are pierced by the intervertebral foramina leading in a caudal and lateral direction into the vertical sacral canals.

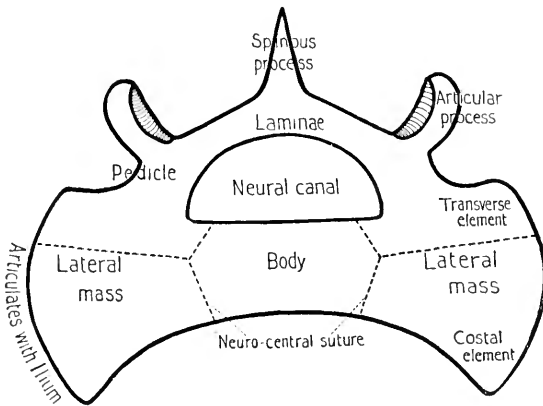
**Nomenclature.**—The Greeks knew this region of the vertebral column as the *hieros spondylos*, the large vertebra. The use of the Latin term *os sacrum*, or sacred bone, has been explained by some writers to be due to the fact that the bone formed an important part of the sacrifices to the gods; according to others, it was introduced into anatomy through an incorrect translation of Galen's *hieros*, which he uses, as was customary, not in the sense of holy, but in place of *megas*, large (A.D. 131–201). The German word is *das Kreuzbein*, the cross-bone, which, however, is said to have nothing to do with cross, as it comes from the old German *cruizi*, an elevation, and refers to a projection backward. The French use *le sacrum*.

**Articulation.**—The sacrum articulates by its cephalic end with



the seventh lumbar vertebra, by its caudal end with the first caudal vertebra, and by the cephalic part of the lateral surface with the ilium of the innominate bone.

FIG. 78.



PLAN OF A SACRAL VERTEBRA. END VIEW.

**Ossification.**—The sacrum appears to be developed from twenty-four centres, whereof nine are the **primary centres**, three for each vertebra. The fifteen **secondary centres** are: six in the epiphyseal plates (two for each body), two in the costal elements of the lateral masses of the first vertebra (Fig. 78), four in the auricular surfaces and lateral margins, and three in the tips of the spinous processes. Further study may show additional centres in the regions of the free and coalesced articular processes.

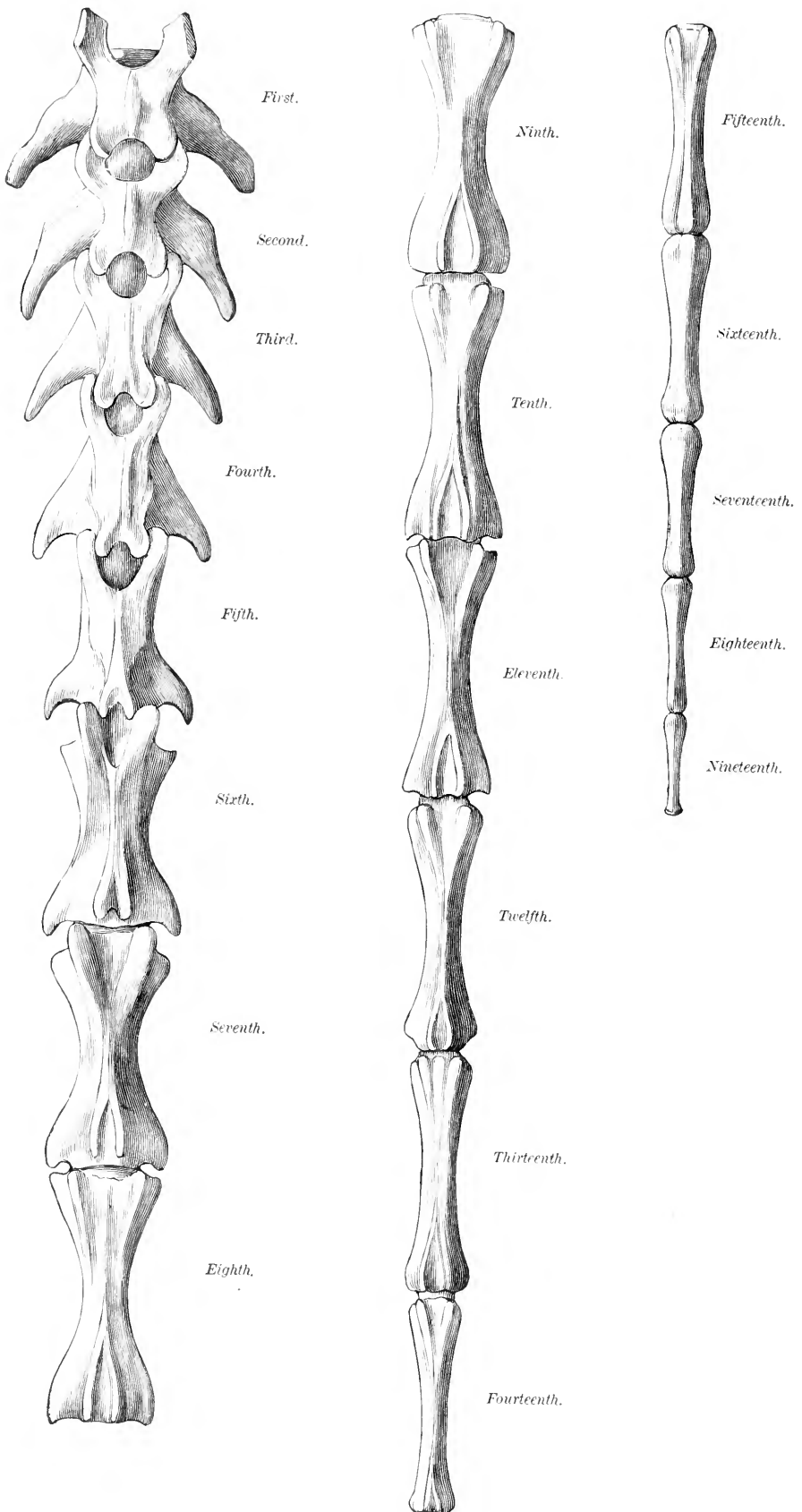
### THE CAUDAL VERTEBRÆ.

The Eighteen to Twenty-six Caudal Vertebræ form the bony support of the tail, constituting about three-sevenths of the entire vertebral column and its slender and most movable region. The first four or five vertebræ are in the terminal movable part of the dorsal wall of the pelvis; the remaining vertebræ are in the part of the tail which projects freely behind the body. The typical caudal vertebræ are in the middle of the region; the first few resemble the sacral vertebræ, and the last five or six are bony cylinders with mere traces of processes.

#### A TYPICAL CAUDAL VERTEBRA.

The **Eighth Caudal Vertebra** (Figs. 79, 80, 81) is a bony cylinder enlarged at both ends. Its long diameter is twice as great as its trans-

FIG. 79.



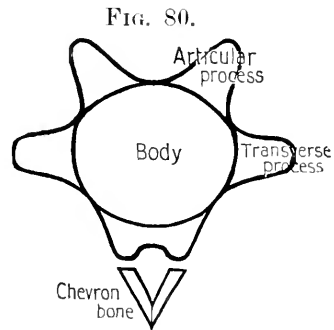
THE CAUDAL VERTEBRÆ, DORSAL ASPECT.

verse or vertical diameter taken at the cephalic end. It consists of little more than an elongated **body**; there is no **neural arch**, and all the processes are reduced to rudimentary ridges. It articulates, therefore, with the adjoining vertebrae only by the ends of the body. Of these, the **cephalic end** is slightly larger and circular, and the **caudal end** is smaller and triangular. The dorsal and ventral surfaces are wider than the lateral surfaces.

The **dorsal surface** (Fig. 79) may be recognized by the possession of a pair of small processes at each end, while the ventral surface has them only at the cephalic end. The **cephalic dorsal processes** are the rudiments of the cephalic articular processes. They are not very long, are compressed from side to side, and are slightly expanded in the cephalo-caudal line. They are separated by almost the entire width of the dorsal surface, at the sides of which they are continued in a caudal direction and also ventrally as more or less elevated lines for some distance. The **caudal dorsal processes** are small tubercles close together, and so near the caudal end of the bone that they form the upper part of the caudal surface. They are placed on a median ridge which begins at the cephalic end between the cephalic processes. This ridge and the processes are the remains of the neural arch and the caudal articular processes.

Each **lateral surface** exhibits along its middle line, at each end, a thin triangular process. These processes are joined by an obscure arched line, into which is blended, caudal to the middle of the bone, the caudal prolongation of the cephalic dorsal tubercles. The two **lateral processes** in this vertebra are of about equal size, and together appear to represent the transverse process of the other vertebrae.

The **ventral surface** (Fig. 81) is less complicated than the dorsal surface. It is gently concave from the cephalic to the caudal end. It is slightly convex from side to side in its caudal part, more strongly convex in the middle, and is elevated in its cephalic part into a pair of longitudinal ridges separated by a distinct groove. The cephalic end of each ridge bears a small conical ossicle which projects toward



PLAN OF A CAUDAL VERTEBRA. END VIEW.

the head and medially, meeting its fellow in the middle line ventral to the caudal border of the ventral surface of the preceding vertebra. This ossicle represents a limb of the small V-shaped hæmal arch, known as a **chevron bone**, which is best developed in the first few caudal vertebræ and is never developed in any other region of the spinal column.

#### TYPE OF THE PROXIMAL CAUDAL VERTEBRÆ.

The **Fourth Caudal Vertebra** (Figs. 79, 81) closely resembles the last sacral, but differs from it in being free, narrower, and longer. The **spinous process** is absent or represented by a low median ridge.

The **body** is longer than the **neural arch**, which is complete and encloses a small triangular neural canal. The **pedicles** slope medially and dorsally, and the **laminæ** are almost horizontal. The **transverse processes** are not prolonged toward the sacrum, but have a caudal and lateral direction and extend far beyond the ends of the caudal articular processes. Their tips are usually slightly bifid.

The **cephalic articular processes** are large, and each shows a trace of a mammillary process. They are separated by a deep median emargination in the cephalic border of the neural arch. The **cephalic articular surfaces** face in a medial and dorsal direction.

The **caudal articular processes** are distinct and horizontal, and the **articular surfaces** face ventrally and laterally.

The **chevron bone** is a small but well-developed arch, and articulates with tubercles on the cephalic end of the ventral surface of the body.

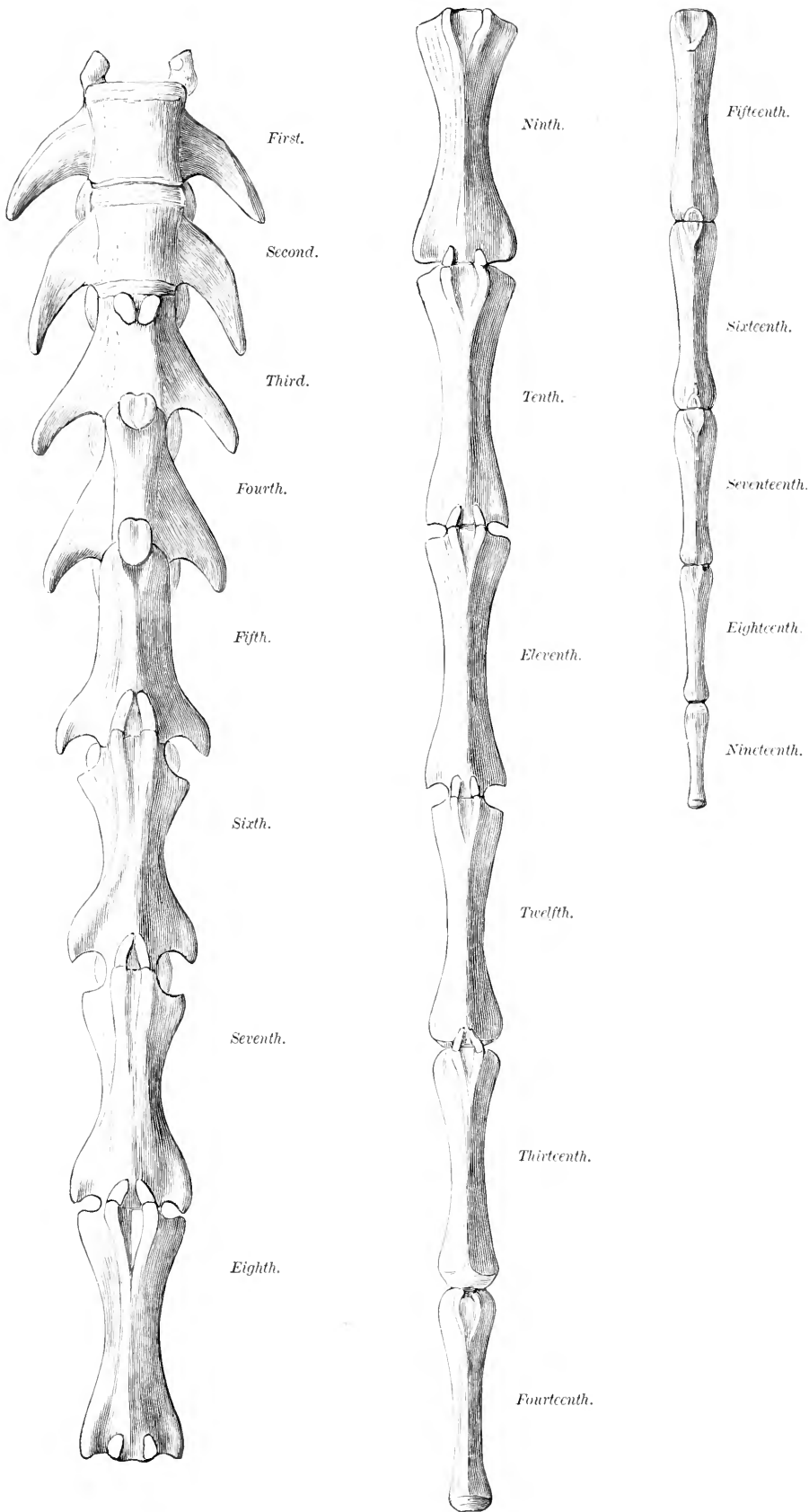
#### TYPE OF THE TERMINAL CAUDAL VERTEBRÆ.

The **Sixteenth Caudal Vertebra** (Figs. 79, 81) is slender, and so greatly elongated that the length is ten or twelve times the width. The reduction of the processes which was begun in the eighth has been here almost completed; the processes are represented by traces of one caudal dorsal, two cephalic dorsal, two lateral, and two cephalic ventral tubercles.

#### DETERMINATION OF CAUDAL VERTEBRÆ.

This determination is not difficult when we are examining the bones taken from one specimen. There is a gradual increase in width and

FIG. 81.



THE CAUDAL VERTEBRÆ, VENTRAL ASPECT.

an increase in length from the first to the tenth and eleventh, beyond which there is a gradual decrease in both length and width. From the beginning to the sixth or the seventh there are **cephalic articular surfaces**. The second vertebra has a distinct cephalic angle on the cephalic edge of the **transverse process**. This angle may appear on the first, usually, however, as a trace only, and also less commonly on the third. The tip of the transverse process is slightly **bifid** on the third, fourth, and fifth or on some one of the three. The **cephalic transverse process** begins at the sixth, and the **caudal articular surfaces** cease at the fifth or the sixth. The **chevron bones** usually become paired ossicles at the eighth. The cephalic and caudal parts of the transverse process have attained equal size at about the eighth.

The neural canal disappears between the seventh and the ninth.

## THE ENTIRE VERTEBRAL COLUMN.

### DORSAL ASPECT.

When the vertebral column is viewed from the dorsal side the **variations** in its **width** are plainly visible. It is wide at the atlas, contracts abruptly and strikingly at the axis, then rapidly widens to the mid-cervical region, whence it gradually and regularly narrows to the eleventh thoracic vertebra; at this point it again begins to widen, and reaches its greatest width at the caudal end of the lumbar region. It narrows again from the cephalic end of the sacrum to the beginning of the caudal region, where, enlarging again slightly, it diminishes in width to the tip of the tail. It will be observed, therefore, that caudal to the atlas the column can be said to be made up of four long truncated pyramids, the first and third with their bases directed toward the tail, and the second and fourth with their bases directed toward the head.

In the middle line of the dorsal aspect of the vertebral column is the **crest** formed by the row of spinous processes, whereof the variation in height and direction can be best seen on the lateral aspect of the column.

On each side of this crest is a long strip, narrow and more or less level. In the cervical region it is formed by the laminae of the vertebrae, and is flat, except where raised by the laminar tubercles. In

the thoracic region the laminae and the upper surfaces of the transverse processes are involved to form a shallow groove which lodges the spinal muscles. From the eleventh thoracic to the end of the lumbar region the strip is made up of laminae only, and the high cephalic articular processes convert it into a narrower longitudinal groove, deeper at the cephalic end of each vertebra and shallower as the lamina rises at its caudal end. The lateral strip becomes wider in the sacrum, and in the tail is continued on the dorsal surface of the transverse processes.

The articular processes of the vertebrae in the cervical region lie far away from the median line; they are nearer the median line and indistinct in the thoracic region back to the eleventh vertebra, where they become prominent, develop mammillary processes, and again gradually get further away from the median line. In the sacral region they are coalesced, but become distinct again in the first few caudal vertebrae.

The dorsal aspect shows, finally, the cephalo-caudal diameter and the lateral extent of all the **transverse processes**. The cephalo-caudal diameter is greater in the atlas, much smaller in the pointed processes of the axis, small in the remaining cervicals, and greater at the beginning of the thoracic region. It then gradually increases to the tenth, inclusive, after which the transverse processes are transformed into the mammillary and accessory processes. What are known as the transverse processes on the lumbar region begin at a lower level as narrow plates, which increase in cephalo-caudal diameter and become pointed and curved toward the head as we proceed toward the sacral region, where the transverse processes are united. The transverse processes in the vertebrae of the tail are narrow and curved in a caudal direction. The length of the transverse processes, measured on a transverse line from their points of origin on the vertebra to their tips, is liable to variation in the different regions of the vertebral column. The length is great in the atlas, small in the axis, whence it gradually increases to the seventh cervical, beyond which it decreases gradually to the tenth thoracic inclusive. From the first to the sixth lumbar it increases again, remains the same at the seventh, and then decreases, with sometimes a slight increase at the first few caudals, until the process disappears in the terminal caudal region.

## VENTRAL ASPECT.

The ventral aspect of the vertebral column is less complicated than either the dorsal or the lateral aspect; it is merely a long strip formed of the ventral surfaces of the vertebral bodies and the ventral edges of their uniting intervertebral disks, and prolonged at each side at intervals on the ventral surface of the transverse processes.

The ventral surface of the column begins wide and flat at the atlas, where the wing-like transverse processes are only slightly dorsal to the ventral arch. It is abruptly narrowed at the axis, whereof the transverse processes contribute little to its formation. It then widens to the fifth cervical, where it begins to narrow again slightly to the seventh. In this region, from the second to the seventh cervical, the ventrally directed costal elements of the transverse processes convert the ventral aspect of the neck into a wide but **deep channel**, which lodges the ventral cervical flexor muscles. In the seventh cervical and the first thoracic vertebra the bodies are flattened and almost continuous at each side with the transverse processes, but as we proceed toward the tail we observe that the bodies become more convex transversely and the transverse processes rise higher on the pedicles, until they disappear on the eleventh thoracic vertebra. Here the vertebral body begins to assume the transversely flattened form it retains for the rest of the thoracic and throughout the lumbar region. At the first lumbar the transverse processes appear again on a level with the ventral surface of the bodies, and are directed ventrally toward the head and laterally, again converting the ventral aspect into a muscular channel, which is continued on the cephalic end of the sacrum. In the caudal part of the sacrum and in the tail there is no such median channel, and the surface of the body and the surface of the transverse processes lie almost in the same plane, with the bodies somewhat convex transversely. In the region of the tail the transverse processes have a caudal and lateral direction as far as the sixth or seventh vertebra, where the cephalic transverse processes begin.

The middle line of the ventral aspect of the vertebral column, in the cervical and lumbar region, is raised into a longitudinal **keel**, and, in the tail, tubercles at the cephalic end of each body support the chevron bones. Since each vertebral body is more or less concave in a cephalo-caudal line, the column, as a whole, is alternately concave and convex in this direction.



## LATERAL ASPECT.

When viewed from the side, it will be seen that the vertebral column is not straight, but curved in the dorso-ventral plane, the degree of curvature of course varying with the movements of the animal. In the position assumed in walking, the column traces but two curves. The **first curve** extends from the cephalic end to the tenth thoracic vertebra, and its **convexity** faces **ventrally**. The **second curve** begins at the tenth thoracic and ceases at the cephalic end of the sacrum, and its **concavity** is **ventral**. The sacrum and first caudal vertebra describe a curve whereof the concavity is ventral, but the tip of the tail is usually somewhat elevated, which causes a fourth curve in the reverse direction from the preceding two.

The lateral aspect of the column shows (1) the length and direction of the spinous processes, (2) the dorso-ventral height of the pedicles and laminae, (3) the diameter of the intervertebral foramina, (4) the point of origin of the transverse processes, and (5) the dorso-ventral height of the bodies of the constituent vertebrae.

(1) The **spinous process** is absent in the atlas, very large in the axis, rudimentary in the third vertebra, and then increases in length to the cephalic thoracic region, where the length remains the same for several vertebrae; it then diminishes to the tenth thoracic, which has the shortest spine of all the trunk vertebrae. From the eleventh the spines gradually increase in length to the end of the lumbar region. They are shorter again in the sacrum and absent in the caudal vertebrae. The fourth, fifth, and sixth cervical spinous processes point dorsally and toward the head, and the seventh cervical and first few thoracic almost directly dorsally; in the remaining thoracics as far as the tenth the spinous processes are directed toward the tail as well as dorsally. The eleventh, the anticlinal, spinous process points dorsally, and marks the point where the two curves of the column join. The remaining spinous processes are directed toward the head as well as dorsally. The tips of the spinous processes are acute in the cervical and thoracic regions, except where elongated in the second cervical, swollen and rounded in the first and second thoracic, and truncated and elongated from head to tail in the twelfth and thirteenth thoracic,—a condition which obtains in all the lumbar vertebrae except the last.

(2) The **pedicles** have a great dorso-ventral diameter in the

cervical and lumbar regions, but a small diameter in those thoracic vertebræ which have transverse processes.

(3) The **intervertebral foramina** are largest in the last cervical, the cephalic thoracic, and the last lumbar vertebræ, and smallest in the mid-thoracic region.

(4) The **transverse processes** spring from the sides of the bodies in the cervical, the lumbar, the sacral, and the caudal vertebræ, and from the pedicles in the thoracic vertebræ. In the cervical region we observe the two parts of the transverse process, the dorsal transverse element and the ventral costal element, coalesced distal to the arterial canal. In the thoracic region the ventral costal element is replaced by the rib, and in the terminal thoracic and the lumbar region the dorsal element becomes the elongated ridge, whereof the cephalic end is the mammillary process and the caudal end the accessory process, while the ventral element is known as the transverse process. In the first and second sacral vertebræ a costal element is developed in the transverse process or lateral mass, and supports the articulation with the innominate.

In the four regions, therefore, the **dorsal element** is represented by

1. The transverse element of the transverse process,
2. The transverse process,
3. The mammillary and accessory processes,
4. The transverse element in the lateral mass.

The **ventral element** is represented by

1. The costal element of the transverse process,
2. The rib,
3. The transverse process,
4. The costal element in the lateral mass.

The cephalo-caudal diameter of the transverse process is relatively great in all the cervical vertebræ except the second and seventh, and also in the ninth and tenth thoracic, the sacral, and those vertebræ of the tail which present both cephalic and caudal transverse processes. In the cervical region the process is directed laterally toward the tail and ventrally; in the thoracic, laterally; in the lumbar, laterally toward the head and ventrally; in the sacral, laterally; in the caudal, laterally and toward the tail.

(5) The bodies are flattened dorso-ventrally in the cervical, cephalic thoracic, sacral, and cephalic caudal regions, and are rela-

tively thick in the remaining thoracic, the lumbar, and most of the vertebræ of the tail.

In works on Comparative Osteology the student will find a system of nomenclature for the parts of a vertebra which differs from that employed in human anatomy, and from that given in the preceding pages. This system was introduced by Richard Owen in his attempt to construct an archetypal or primitive vertebra. In it the processes are termed apophyses, and their differences in position and function are indicated by different Greek prefixes. The relation at present between the two systems may be shown as follows :

Neurapophysis = spinous process.

Prezygapophysis<sup>1</sup> = cephalic articular process.

Postzygapophysis = caudal articular process.

Metapophysis<sup>2</sup> = mammillary process.

Anapophysis<sup>3</sup> = accessory process.

Diapophysis<sup>4</sup> = a transverse process articulating with the tubercle of the rib; hence the transverse element of the cervical transverse process.

Parapophysis<sup>5</sup> = a transverse process from the body of a vertebra articulating with the head of the rib; hence the proximal part of the costal element of the cervical transverse process.

Pleurapophysis<sup>6</sup> = a rib, or an ossification which is rib-like in position, as the distal part of the costal element of the cervical transverse process, or the tip of the lumbar transverse process.

Epapophysis<sup>7</sup> = ridge on dorsal surface of body.

Hypapophysis<sup>8</sup> = ridge on ventral surface.

Hyperapophysis<sup>9</sup> = tubercle on cervical laminae.

Hæmapophysis<sup>10</sup> = chevron bone.

#### VARIAIONS IN VERTEBRÆ.

The variations in the vertebræ may be classified as—(1) Variations in size, and in degree of development of their parts. (2) Variations in the number in any region. (3) Malformations due to defective development.

<sup>1</sup> *Zygon*, a yoke.

<sup>2</sup> *Meta*, after, beyond.

<sup>3</sup> *Ana*, backward.

<sup>4</sup> *Dia*, across, between.

<sup>5</sup> *Para*, beside.

<sup>6</sup> *Pleura*, rib.

<sup>7</sup> *Epi*, upon.

<sup>8</sup> *Hypo*, under.

<sup>9</sup> *Hyper*, above.

<sup>10</sup> *Hæma*, blood.

## VARIATIONS IN SIZE AND DEVELOPMENT.

We may take as examples the atlas, the axis, and the sacrum.

## THE ATLAS—VARIATIONS IN SIZE.

Cephalo-caudal diameter of body.	Maximum width across transverse processes.	Cephalo-caudal diameter of neural arch.	Dorso-ventral diameter of caudal opening of neural arch.	Transverse diameter of neural arch at dorsal end of caudal articular process.
<sup>1</sup> 3	29	7	11	11
3.5	29	7	11	11
3.5	29.5	7	10	11
3.5	30	8	10	11
3.5	31	8.5	11	10
3.5	32	8.5	11	11
3.5	34.5	7	12	12
4	30	9	10	11
4	30	8	11	11
4	31	8	11	11
4	31	8	10	10
4	31	8	10	11
4	31	8.5	11	11
4	31.5	9	10	11
4	31.5	8	11	15
4	31.5	9	11	11
4	32	8.5	11	10
4	32	9	10	10
4	33	8	11	12
4.5	30.5	7.5	11	10
4.5	32	8	11	11
4.5	33	8.5	11	12
4.5	33.5	8.5	10	11
4.5	33.5	10.5	11	11
4.5	34.5	9	10.5	10
4.5	34.5	9	11	11
4.5	35	8	10.5	12
4.5	35	9	11.5	11
4.5	36	9.5	11	12
4.5	36.5	10	11.5	13
4.5	38	9	11	12
4.5	38	10	12	12
5	32	10	10.5	11
5	32.5	9.5	11	10.5
5	34.5	8.5	12	12
5	35	10	11	11.5
5	35.5	11	12	11
5	35.5	10	12	11.5
5	37	10	12	12
5	37	10	11	11.5
5	36.5	10	11	13
5	39	11	11	12
5.5	34.5	9	11	11
5.5	35	10	11.5	12
5.5	39	9	11	12
5.5	39	10	11.5	11
5.5	41	11	13	12
6	39.5	10	11	11
6	39.5	10	12	11

<sup>1</sup> The measurements are given in millimetres.

## THE ATLAS—VARIATIONS IN DEVELOPMENT.

The cephalic margin of the **neural arch** may be straight or gently emarginate, with a single median tubercle or with two strong tubercles. The caudal margin, dorsal to the caudal articular processes, may be incised or straight. The arterial foramen on each side of the cephalic end of the laminae may be merely a notch in the cephalic margin, owing to the failure of the cephalo-medial wall to ossify. The foramen may be double. This appears to be a variation comparatively rare, inasmuch as it was found only once, and on the right side, in an examination of seventy-five specimens.

A trace of a **neural spine** as a cephalic dorsal tubercle has been observed in three out of fifty specimens.

The dorsal surface of the **body**, just caudal to the cephalic edge, is sometimes marked by a transverse ridge on the line of attachment of a ligament. The longus colli tubercle on the caudal margin may be absent.

The cephalic margin of the **cephalic articular processes** may project beyond the neural arch or may be almost on a line with it. Their articular surfaces may continue on the cephalic margin of the body. In some specimens the caudal articular surfaces encroach upon the edge of the body.

The edge of the **transverse process** is sometimes prolonged and united with the cephalic articular process, converting the arterial groove into an additional lateral foramen. The edge is subject to much variation in the degree of curvature. The caudal margin may be separated from the caudal articular surface by a deep notch, or the two may be continuous. In some cases an oblique ridge on the ventral surface, caudal to the area of origin of the levator claviculae, separates the caudal articular process from the transverse process.

The cephalic opening of the **arterial canal** may be cephalic or caudal to the middle of the cephalo-caudal diameter of the root of the transverse process. The arterial groove cephalic to the foramen is shallow or deep, and occasionally is converted into a cleft by the turning ventrally of that part of the transverse process. One of the caudal arterial foramina may be larger than the other.

## THE AXIS—VARIATIONS IN SIZE.

Length of spine.	Cephalo-caudal diameter of body.	Maximum transverse diameter.	Dorso-ventral diameter of vertebra.	Transverse diameter of neural canal.	Dorso-ventral diameter of neural canal.
22	22	14.5	19	9	10
22.5	21.5	15	19.5	8.5	8
22.5	21.5	14.5	19.5	9	8.5
22.5	23	15.5	20.5	9	10
22.5	26.5	16	19.5	10	10.5
23	23	15	19	8.5	8
23.5	23.5	15.5	18	9	8
23.5	22	14	18.5	7.5	9
24	23	14.5	19	8	8.5
24	24	15	18.5	8	9.5
24	23	15	20	9	9
25	24	15	20	9	9
25	23	15.5	19	8	9
25.5	22.5	15	21	9	9.5
25.5	23.5	16	19	9	9
25.5	24	16	21.5	9	9.5
26	24.5	17	22	10	9.5
26	31.5	16	20	9.5	9
26	23.5	15	19	8.5	9
26	25	15	20.5	9	9
26	24.5	14	20	8.5	10
26	25	15.5	20	9	10
27	26.5	15	20.5	9	9
27	24	15.5	18.5	9	9
27	25	16.5	21	9	10
27	25	16	22.5	10	10.5
27.5	24	16	21	9	9.5
28	25.5	17	22.5	9.5	9.5
28	26	16	22	9	11
28.5	26	15	20	8.5	9.5
29	26	16.5	22	8.5	10
30	25	16.5	20.5	9.5	8.5
31	23.5	17.5	21	9	9.5
31	26.5	16.5	22.5	9.5	10

## THE AXIS—VARIATIONS IN DEVELOPMENT.

The cephalic end of the spinous process may project slightly beyond the end of the odontoid process, or may reach only to its base. This latter condition is due in part to the more marked caudal inclination of the pedicles. In some cases the ventral edge of the tip of the spinous process is a broad smooth surface which rests on the neural arch of the atlas.

The caudal surface of the laminae may be elevated into a strong median crest or may be entirely depressed.

The transverse process is not the subject of much variation. Its tip may be laterally compressed and not pointed.

The odontoid process varies slightly in shape and size; its direction

may be cephalic or cephalic and dorsal. The facet on its ventral surface is occasionally decidedly concave. The dorsal surface is sometimes deeply grooved transversely where it passes ventral to the transverse ligament of the atlas. In some specimens the tip of the process is rough and irregular.

#### SEVENTH CERVICAL VERTEBRA—VARIATIONS.

The most important variation in the seventh cervical is the presence of an **arterial canal** in the transverse process. An examination of fifty specimens revealed the canal twice on one side only, three times on both sides, and once as a deep notch on the ventral surface, probably converted into a foramen by a fibrous band.

#### THE SACRUM—VARIATIONS IN SIZE.

Maximum width.	Minimum width.	Lesser width.	Length of body.	Maximum height.
23	15.5	. .	23	17
24	12.5	. .	21	15
24	13	17	22	17
24	14	20.5	23	16
24.5	14	19.5	23	18
25	12	18	24	16
25	13	. .	21.5	15
25	14	19.5	23	18
26	13.5	18.5	20	17
26	13.5	22	24	19
26	14	19	28	18
26	15	18	23	18
27	12	. .	25	20
27	14.5	22	25.5	18
27	15	16	27	20
27	16	20	26	18
27	17	21	23.5	20
27.5	13.5	18	23	16.5
28	13	. .	24	17
28	14	21	24	16
28	15	18.5	25.5	23
28	16	22	25.5	21.5
28	16	22.5	25	18
28	16.5	21	25	16
28.5	15	22	27	17.5
29	11.5	17.5	26	15
29	12.5	. .	23	17
29	14	20	26	19.5
29	16	. .	24.5	20
29	17	19.5	26.5	22.5
31	13.5	21	27.5	20.5
31	15.5	18.5	26	18
31	16	23	26	20
33	16	17	26	22

## THE SACRUM—VARIATIONS IN DEVELOPMENT.

The **spinous process** of the third vertebra may be rudimentary or coalesced by its cephalic border with the spinous process of the second vertebra; rarely the first spinous process is smaller than the second (three cases in thirty-five).

The **cephalic articular processes** are either low, with their articular surfaces facing dorsally more than medially, or high, with their surfaces facing directly toward the middle line. The emargination which separates them may be wide and shallow, or narrow and deep.

The **laminæ** often exhibit along their lines of coalescence irregular openings or small, definite foramina.

The outline of the **lateral mass** varies from almost circular to triangular; hence the shape of the auricular surface also varies; it may extend, on the narrow lateral border of the sacrum, beyond the first dorsal foramen.

The **ventral surface** may be very flat or convex, either transversely and in a cephalo-caudal direction, or in one of these directions only. These differences in curvature appear to be independent of sex.

The **sacral foramina** vary in size, but no case is noted of the entire absence of any of them.

## VARIATIONS IN THE NUMBER OF VERTEBRÆ.

In a specimen described<sup>1</sup> as having fourteen **thoracic vertebræ**, the additional rib on each side was small (one to one and a half inches in length), and its point of attachment to the vertebra was similar to that of the rib of the preceding vertebra and to that of the transverse process of the succeeding vertebra. The change in the articular processes from the thoracic to the lumbar type was completed between the eleventh and twelfth vertebræ, but the caudal articular processes of the tenth, although of a dorsal type, presented transitional changes.

I have observed several instances of an increase in the number of the **lumbar vertebræ**, but the eighth lumbar was always attached, in a greater or less degree, to the sacrum, and its coalesced transverse process or processes assisted in the formation of the sacro-iliac articu-

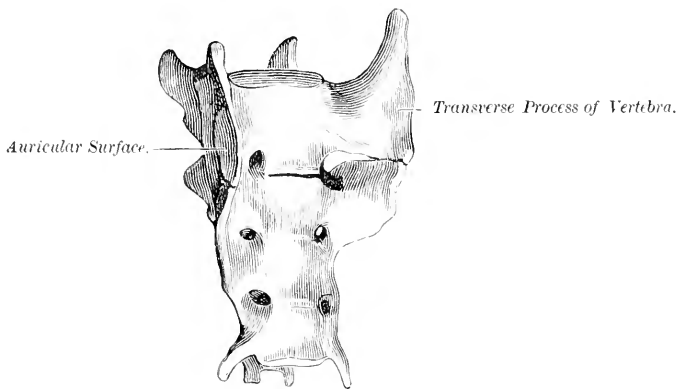
<sup>1</sup> Struthers, *Jour. Anat. and Phys.*, 1875, p. 64.



lation. In these specimens the seventh lumbar has rudimentary accessory processes, the laminae are longer than a normal seventh, and the emargination between the caudal articular processes is less pronounced.

The **sacrum** may be increased by the addition of a vertebra to its cephalic end or by the coalescence of the first vertebra of the tail with its caudal end. In the former case the addition may be at the expense of the lumbar region (Fig. 82), and thereby represent a more cephalic

FIG. 82.



SACRUM PARTIALLY UNITED WITH SEVENTH LUMBAR VERTEBRA.

attachment of the pelvic girdle to the axial skeleton, or the addition may be associated with an increase in the number of the lumbar vertebrae, and thereby represent an attachment of the pelvic girdle more than usually caudal.

Coalescence of the caudal vertebrae with the sacrum has been noted; more frequently, however, the last sacral is free, either completely or still showing traces of coalescence between the transverse processes.

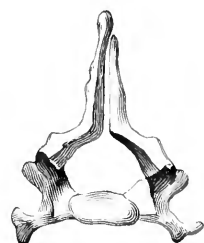
The **caudal** vertebrae are subject to some variation in number, probably not to the extent commonly supposed; it is difficult to preserve the small terminal ossicles. The relation between the variations in number and the variations in their peculiar features is shown in the following table. The vertebrae are numbered from the sacrum, and those which are indicated by bold-faced type exhibit the features most distinctly.



MALFORMATION OF VERTEBRÆ.

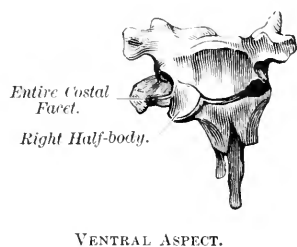
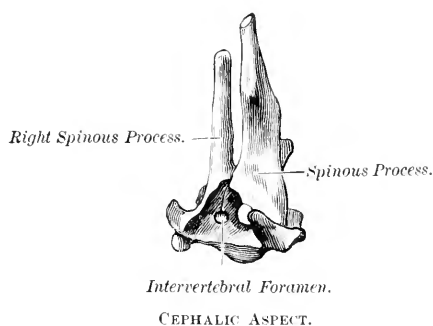
A malformation may be confined to one vertebra, the result usually of a failure of the parts to unite, as in the case illustrated (Fig. 83), where the halves of the spinous process still remain distinct. A malformation may involve two or more vertebræ and be due to a dislocation during development of the centres of ossification. In the specimen of the second thoracic vertebra shown in Fig. 84 the body appears to be normal, except for the union with it of the right half-body of the next vertebra; its neural arch, however, is completed on the right side by half the neural arch of the next vertebra; its own half neural arch is distinct and terminates in a smaller right spinous process; this half neural arch is recognized as belonging to this vertebra, and not to the ver-

FIG. 83.



ABNORMAL VERTEBRA.

FIG. 84.



ABNORMAL THORACIC VERTEBRA.

tebra immediately preceding, because the features on its transverse process are similar to the features on the single left transverse process.

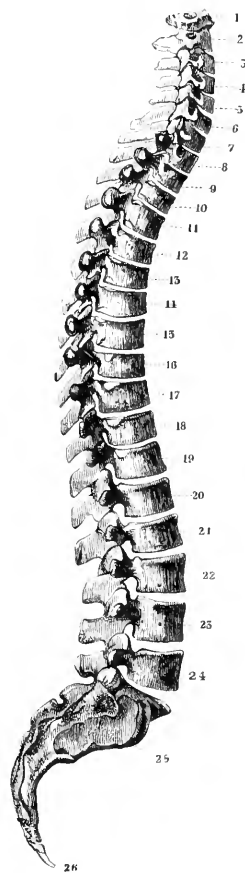
HUMAN VERTEBRAL COLUMN.

The vertebral column occupies a vertical position in the human body; hence in most works on anatomy the terms superior and inferior are used instead of cephalic and caudal, and anterior and posterior instead of dorsal and ventral. The student will find no difficulty in changing from one set of names to the other.

When we compare the human vertebral column (Figs. 6, 85) with that of the cat, we observe that it is relatively much shorter; it

possesses but thirty-three vertebræ, whereof seven are cervical, twelve thoracic, five lumbar, and the lower nine are coalesced into two superimposed masses,—namely, the sacrum, of five vertebræ, and the coccyx, or rudimentary tail, of four vertebræ. It also appears to be more compact, its dorso-ventral and transverse diameters increasing

FIG. 85.



THE VERTEBRAL COLUMN.  
LATERAL VIEW.

Exhibiting the curvatures. 1 to 24, true vertebræ; 25, 26, false vertebræ; 1 to 7, cervical vertebræ; 8 to 19, thoracic vertebræ; 20 to 24, lumbar vertebræ; 25, sacrum; 26, coccyx.

gradually and with few irregularities from the head to the sacrum. Inasmuch as it is vertical, it bears the weight of the upper part of the body; hence all the vertebral bodies and all the pedicles and laminae are compressed from above downward, and none of the spinous processes point toward the head. Owing to direct downward pressure, the column describes four curves in the median plane, whereof those in the cervical and lumbar regions have the convexity ventral and those in the thoracic and sacro-caudal regions have the convexity dorsal.

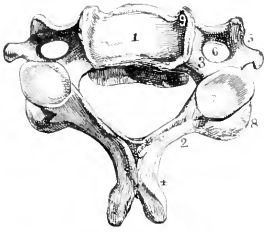
#### HUMAN CERVICAL VERTEBRÆ.

The **Sixth Cervical Vertebra** (Fig. 86) compared with the sixth of the cat is relatively wider. The ends of the broad and flattened body are concave transversely and scarcely bevelled. The arterial canal in the transverse process is very large; the transverse process itself, however, is simple, and the costal element is rounded at the end. The pedicles are shorter and almost columnar, and incline laterally as well as dorsally. The laminae meet each other at a right angle, and the cephalic end is emarginate. The spinous process is short and bifid at the tip, which inclines toward the sacrum. The cephalic articular surfaces (called “superior” in the illustration) face dorsally and toward the head; the caudal articular surfaces (called “inferior” in the illustration) face ventrally and toward the sacrum. The cephalic intervertebral notches are very evident.

The human **Seventh Cervical** differs from the corresponding vertebra of the cat in having an arterial canal in its large transverse

process. The costal element is much reduced, however, and sometimes absent; on the other hand, it may be enlarged to such an extent as to constitute a cervical rib,—a condition not yet reported as occurring

FIG. 86.



A CERVICAL VERTEBRA.  
UPPER VIEW.

1, centrum; 2, lamina; 3, pedicle; 4, spinous process; 5, transverse and costal processes; 6, foramen for the vertebral artery; 7, superior articular process; 8, inferior articular process; 9, elevated lateral border of the centrum.

in the cat. The *laminæ* are the largest of any of the cervical series, and the *spinous process* is the longest (hence this vertebra has been called the *vertebra prominens*); its tip, however, is not normally bifid.

The Third, Fourth, and Fifth Cervical Vertebrae are very much alike, and are to

be distinguished by their relative size, the third being the smallest and the fifth the largest.

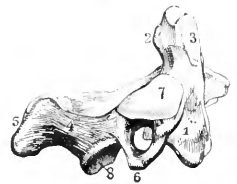
The *Axis* (Fig. 87) presents all the features possessed by the axis of the cat, but the cephalo-caudal diameters of all the parts are much diminished.

The *body* is quadrate, and its *odontoid process* is long and stout. The *pedicles* are short and narrow; the *transverse processes* are small and simple and pierced by large arterial canals. The *cephalic articular processes* are circular and flat or slightly saddle-shaped; their surfaces face toward the skull and laterally. The *caudal articular processes* resemble the processes of the other cervical vertebrae; their surfaces face toward the sacrum and ventrally. The *laminæ* are longer than the laminæ of the other vertebrae; the *spinous process* is short and bifid. The *neural canal* is almost round.

The *Atlas* (Fig. 88) as compared with the atlas of the cat is merely a ring of bone.

The *ventral bar* (anterior arch) is slightly wider than the *dorsal bar* (posterior arch), which bears a trace of the spinous process. The *transverse processes*, instead of being large and wing-like, are small masses, whereof the bases are pierced completely by the arterial canals.

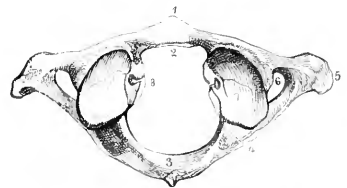
FIG. 87.



THE AXIS. SIDE VIEW.

1, centrum; 2, odontoid process; 3, articular facet; 4, arch; 5, spinous process; 6, transverse process, with the vertebral foramen; 7, 8, superior and inferior articular processes.

FIG. 88.



THE ATLAS. UPPER VIEW.

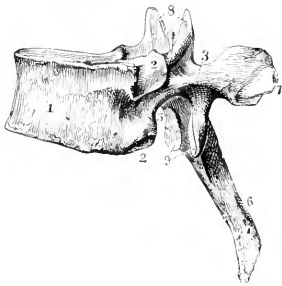
1, anterior arch; 2, articular facet for the odontoid process; 3, posterior arch; 4, groove for the vertebral artery; 5, transverse process; 6, vertebral foramen; 7, superior articular process; 8, tubercle for the transverse ligament.

The costal element is shorter than the transverse element. The groove on the side of the body for the vertebral artery is short and deep, and the foramen for the artery and the first spinal nerve is a canal in the pedicle. The cephalic articular surfaces are less cup-shaped than the corresponding surfaces on the cat's atlas; the caudal articular surfaces encroach to a great extent upon the lumen of the neural canal, offering medial roughened surfaces for the attachment of ligaments.

### HUMAN THORACIC VERTEBRÆ.

The Sixth Thoracic Vertebra in man (Fig. 89) differs from the corresponding vertebra in the cat principally in the relative decrease in the cephalo-caudal diameters of all its parts and in the greater inclination of the spinous process. The dorso-ventral diameter of the body is greater than the transverse diameter, the cephalic and caudal surfaces are cordiform, or heart-shaped, and their edges are margined by an elevated band. The dorsal surface is not keeled. The neural canal is round. The cephalic articular processes are more distinct than on the cat's vertebra. The transverse processes are longer and more slender, and the ends are not expanded; hence the ventral articular facet for the tubercle of the rib is less conspicuous.

FIG. 89.



A THORACIC VERTEBRA.  
SIDE VIEW.

1, centrum; 2, articular facets for ribs; 3, arch; 4, 5, intervertebral notches; 6, spinous process; 7, transverse process; 8, superior articular processes; 9, inferior articular processes.

The transverse processes are longer and more slender, and the ends are not expanded; hence the ventral articular facet for the tubercle of the rib is less conspicuous. They have, however, a decided dorsal inclination. The spinous process is relatively short, and the tip is obliquely truncated.

The spinous process is relatively short, and the tip is obliquely truncated.

When the other human thoracic vertebræ (Fig. 85) are examined, the student will observe that they are all very similar and that the characters which serve to distinguish the different thoracic vertebræ of the cat are here of less value.

The bodies increase in size gradually from the first vertebra to the last, which has the shape and most of the characters of a lumbar vertebra.

In the first and second vertebræ the transverse diameter of the body is greater than the dorso-ventral diameter; from the third to the seventh, approximately, the dorso-ventral diameter is the greater; in the remaining thoracic vertebræ the two diameters are at first nearly

equal, then the transverse again becomes the greater. The first vertebra resembles a cervical in having the ends of the body excavated, the transverse processes longer, and the spinous process less inclined.

The end of the transverse process is simple in the vertebræ near the neck, irregular in the eleventh, and bifid in the twelfth to form the mammillary and accessory processes. The tubercular articular facets on the transverse processes are deepest on the second vertebra and are absent on the eleventh and twelfth.

A single costal facet is present on each side of the body of the tenth and eleventh and on the side of the pedicle of the twelfth vertebra.

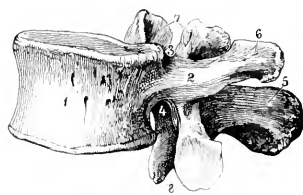
The eleventh vertebra is the anticlinal vertebra, because, although none of the spinous processes have a cephalic inclination, its process marks the point at which the remaining processes begin to have a dorsal direction only.

The caudal articular processes of the twelfth thoracic vertebra face laterally rather than ventrally; hence they are seen when the vertebra is viewed from the side.

### HUMAN LUMBAR VERTEBRÆ.

The five lumbar vertebræ of man (Figs. 85, 90) differ very much in appearance from the lumbar vertebræ of the cat. Their bodies are so greatly compressed that their cephalo-caudal diameter is the smallest of the three. Their pedicles are not large plates, but columns; their laminæ are narrow and enclose a triangular neural canal. The transverse processes are narrow and project laterally and slightly dorsally; those of the first and second vertebræ are the longest, those of the fourth the most pointed, while those of the fifth are swollen at the tip. The mammillary and accessory processes are little more than tubercles. The spinous processes are thick and broad. The cephalic articular surfaces face medially and to a less extent dorsally; the caudal articular surfaces face laterally and ventrally.

FIG. 90.



A LUMBAR VERTEBRA.  
SIDE VIEW.

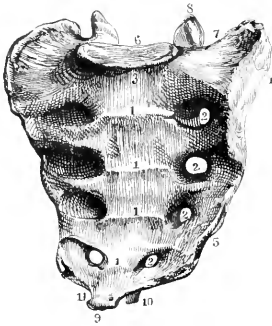
1, centrum; 2, side of the arch; 3, 4, intervertebral notches; 5, spinous process; 6, transverse process; 7, superior articular processes; 8, inferior articular processes.

The last lumbar vertebra may be always recognized by the small cephalo-caudal diameter of its laminae and by its pointed spinous process.

### HUMAN SACRUM.

The human sacrum (Figs. 91, 92) is composed of five coalesced vertebrae; hence it is, relatively, a larger mass than the sacrum of

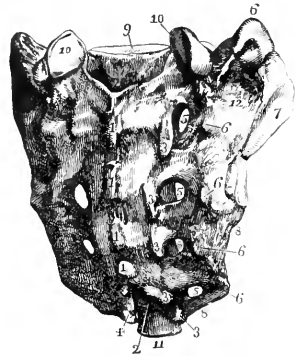
FIG. 91.



SACRUM. FRONT VIEW.

1, transverse ridges, indicating the original separation of the bone into five segments; 2, sacral foramina; 3, promontory; 4, articular surface for the hip-bone; 5, sacral border of the sacro-sciatic notch; 6, base of the sacrum, with its articular surface for the last lumbar vertebra; 7, wing of the sacrum; 8, superior articular process; 9, apex of the sacrum, with its articular surface for the coccyx; 10, cornu of the last vertebral arch; 11, notch for the last sacral nerve.

FIG. 92.



SACRUM. BACK VIEW.

1, rudimentary spinous processes; 2, 2, sacral canal; 3, 3, rudimentary articular processes; 4, cornu; 5, sacral foramina; 6, 6, rudimentary transverse processes; 7, articular surface for the hip-bone; 8, sacral border of the sacro-sciatic notches; 9, articular surface for the last lumbar vertebra; 10, superior articular processes for the latter bone; 11, apex of the sacrum; 12, rough surface on the wing of the sacrum, for the sacro-iliac ligaments.

the cat, and presents, instead of twelve, sixteen **sacral foramina**,—four on each side of the ventral surface and four on each side of the dorsal surface. It has five tubercular **spinous processes**.

The **auricular surface**, for articulation with the innominate bones, is longer and narrower, extending on the lateral surfaces of the first three vertebrae.

The **dorsal surface** is rougher and the strip lateral to the sacral foramina is wider; its cephalic portion, known as the **sacral tuberosity**, is formed at the expense of the lateral surface.

The human sacrum is decidedly curved in the cephalo-caudal line, the concavity facing the ventral side. It is less curved and is wider in women than in men.



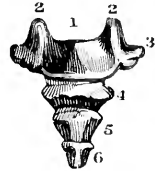
HUMAN CAUDAL VERTEBRÆ.

Man possesses a short tail, in the form of a bony mass composed of four or five rudimentary caudal vertebræ and known as the **coccyx**<sup>1</sup> (Fig. 93).

The **First** and **Second Vertebræ** exhibit, in addition to a body, traces of articular and transverse processes; the **Third** and **Fourth**, and the **Fifth** when present, are mere nodules of bone.

The coccyx has **no neural canal**. The junction of the coccyx and the sacrum produces four additional sacral foramina.

FIG. 93.



COCCYX. POSTERIOR VIEW.

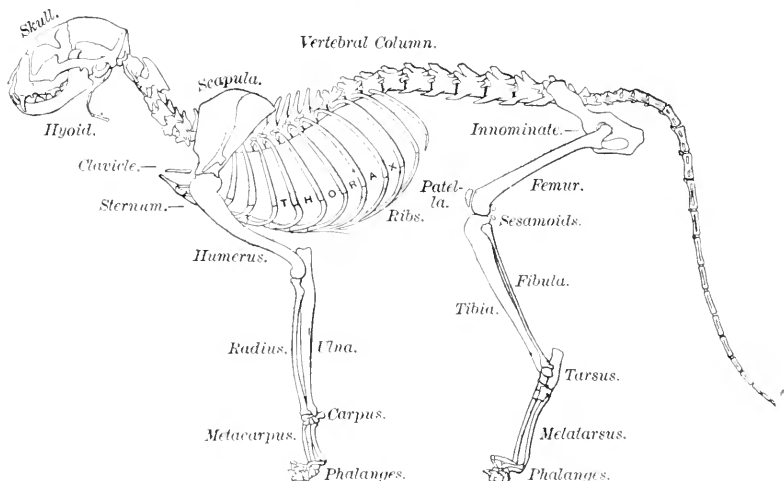
1, first segment; 2, 2, the cornua; 3, transverse process; 4, 5, 6, lower three coccygeal vertebræ.

<sup>1</sup> (Gr.) a cuckoo, from a fancied resemblance to a cuckoo's beak.

## CHAPTER III

## THE RIBS, THE STERNUM, AND THE THORAX

FIG. 94.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

## THE RIBS.

THE Ribs are slender, curved bars which form the greater part of the chest-walls. They consist of **thirteen pairs**, each pair composed of a right and a left rib. The thirteen pairs are arranged parallel to one another, and with their long axes directed, in general, from the dorsal to the ventral side of the body. Their dorsal ends are attached to the vertebral column, and the ventral ends of most of them join the sternum. A typical pair of ribs, therefore, forms with a vertebral body and with a joint of the sternum a ventral ring, sometimes called a *hæmal arch*. The thirteen hæmal arches together form the conical cage known as the thorax or chest.

The ribs are divided into two classes,—namely, the true ribs and the false ribs.

The **true ribs** are the cephalic nine pairs, the ventral ends of which directly join the sternum.

The **false ribs** are the caudal four pairs, which do not directly

join the sternum. The ventral ends of the cephalic three pairs of these—the tenth, the eleventh, and the twelfth—are indirectly attached to the sternum through the union of their ventral parts with one another and with the ventral part of the ninth pair. The ventral ends of the thirteenth pair are more free, and are embedded in the muscles of the abdominal wall; hence these ribs are termed **floating ribs**.

The true ribs are also called **vertebro-sternal ribs**; the false ribs, **asternal ribs**; and the floating ribs, **vertebral ribs**.

Each rib is formed of two distinct elements,—a longer, dorsal, bony portion, to which the name **rib** is commonly restricted, and a shorter, ventral, cartilaginous portion, known as the **costal cartilage**. The bony ribs form the dorsum and most of the sides of the thorax; the costal cartilages with the sternum constitute the ventral wall and the ventral part of the sides.

The ribs increase in length from the cephalic end of the thorax, and the costal cartilages rise more dorsally on the side-walls of the thorax at the caudal end than they do at the cephalic end.

#### CHARACTERS OF A TYPICAL RIB.

The **Fifth Rib** (Figs. 95, 96) may be selected for study, since it lies in the middle of the thoracic wall and thus presents an average size. It is also in relation dorsally with an average thoracic vertebra and ventrally with an average sternebra. We shall consider first the rib and then the costal cartilage.

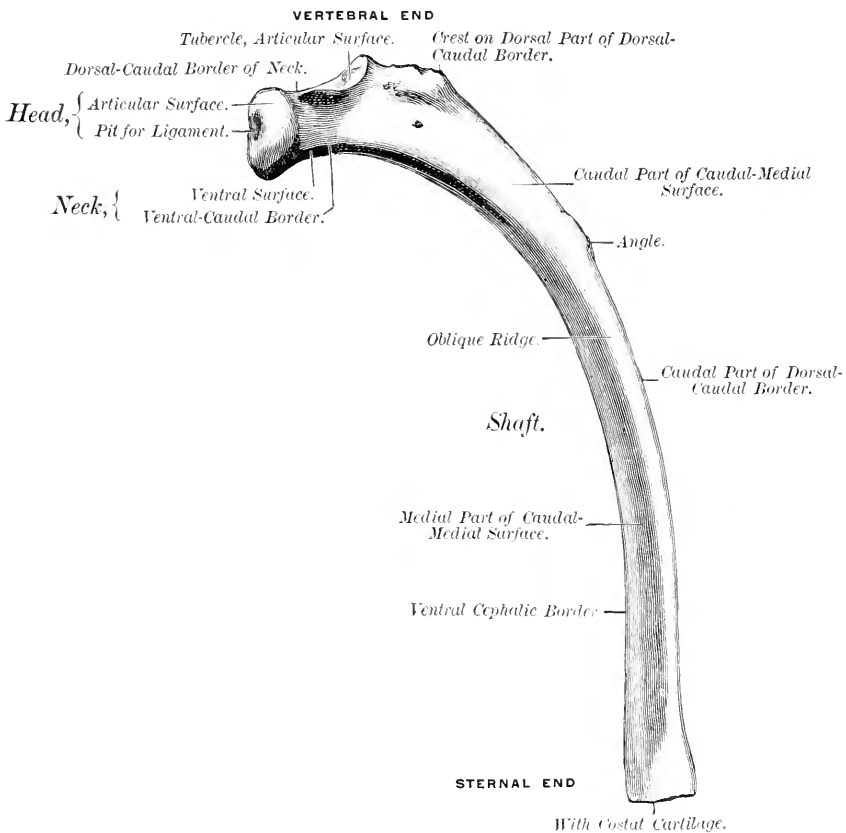
The **RIB** (Fig. 95) is a slender, curved bar, about ten times as long as wide. Its ventral or sternal half is flattened and slightly curved. Its dorsal or vertebral half is thicker and strongly curved. The rib presents a head separated by a neck from the shaft.

The **Head** is the rounded, vertebral extremity of the bone. It is very little wider or higher than the neck, and presents a smooth, semi-spherical **surface**, which faces medially, dorsally, and toward the head and articulates with the bodies of the fourth and fifth vertebrae. A vertical **ridge** with a central **pit** divides the articular surface of the head into **two convex facets**, whereof the cephalic and larger articulates with the half-facet on the body of the fourth vertebra and the caudal and smaller articulates with the half-facet on the body of the fifth vertebra. A strong ligament from the intervertebral disk is

attached to the ridge which separates these facets and converts this costo-vertebral joint into two distinct synovial cavities.

The **Neck** is of small extent, and is little narrower than the head. It is four-sided, with the dorsal and ventral sides somewhat narrower than the cephalic and caudal sides. The **dorsal surface** is convex from the cephalic to the caudal edge and concave from the lateral to the medial end, and forms, with the concave ventral surface of the transverse process, an arterial **costo-vertebral canal** (Fig. 44). The

FIG. 95.



FIFTH RIGHT RIB. POSTERIOR OR CAUDAL ASPECT.

**cephalic** and **caudal surfaces** are convex from the dorsal to the ventral edge, and very nearly flat from end to end. The **ventral surface** is longer than the dorsal, owing to the oblique position of the articular surface on the head. It is slightly concave from end to end, and convex from the cephalic to the caudal edge.

At the junction of the neck with the shaft, on the dorsal aspect of the rib, is a flattened, oval elevation known as the **tubercle**. It is

not prominent, but is a little larger than the surface from which it rises. Its entire dorsal surface is occupied by a smooth **facet**, which articulates with the facet on the ventral surface of the transverse process of the fifth vertebra. The **articular surface** is gently saddle-shaped, concave from end to end, and convex from the cephalic to the caudal edge. It faces dorsally and toward the tail.

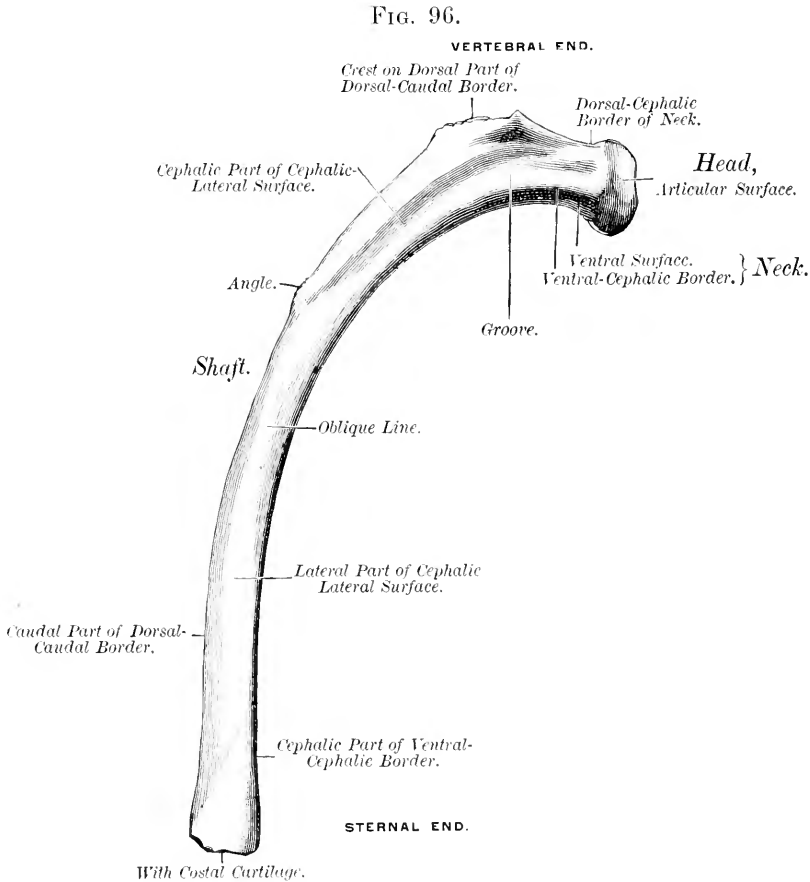
The **Shaft** of the rib comprises the rest of the bone. Its vertebral part curves strongly laterally and ventrally to a point dorsal to the junction of the dorsal with the middle third, where it becomes less arched and is directed more vertically. The point at which this change in the dorso-ventral curvature takes place is known as the **angle** of the rib, and is usually marked by a roughened prominence, sometimes elevated into a decided tubercle, for the attachment of the ilio-costal muscle.

At the angle, the rib makes a slight bend ventrally and toward the tail. The angle also marks the point at which the rib begins to be twisted about its own long axis. Dorsal to the angle it is flattened from edge to edge and presents cephalic and caudal surfaces separated by dorsal and ventral borders. Below the angle the rib becomes rounded and then gradually flattened from without inward, and the cephalic surface gradually turns, to become entirely lateral at the ventral end. The caudal surface becomes medial, and the dorsal and ventral borders become the caudal and cephalic borders respectively.

The **caudal-medial surface** (Fig. 95) is the continuation of the caudal and ventral surfaces of the neck. It is concave dorso-ventrally for most of its extent, but is almost flat in its sternal part. It is more convex in the vertebral part than in the sternal part, and narrower in the middle. It is divided into definite vertebral and sternal parts by a ridge, or line of maximum convexity, beginning as the continuation of the caudal-ventral border of the neck, arching ventrally and laterally, and joining the dorsal-caudal border in its sternal third. The vertebral part is the continuation of the caudal surface of the neck. It is a curved triangular strip, wide at the vertebral end and pointed at the sternal end. It is depressed or even slightly excavated at its vertebral end, but, in the main, flat or somewhat convex from dorsal to ventral border. It faces toward the tail, and, in a certain degree, medially. On it lie the intercostal vessels. The sternal part of the

caudal-medial surface is the continuation laterally and ventrally of the ventral surface of the neck. It is not always well defined from the preceding part. It is narrower at the vertebral end than at the sternal end, and is flat from edge to edge. Its vertebral part is strongly concave dorso-ventrally, and faces medially and ventrally. Its sternal part is nearly straight, and faces medially and toward the tail.

The cephalic-lateral surface (Fig. 96) is arched dorso-ventrally.



FIFTH RIGHT RIB. ANTERIOR OR CEPHALIC ASPECT.

It is wider in the vertebral part than in the sternal part, and more convex from edge to edge in the middle than at either end. Its vertebral part, flattened and often marked by a linear groove, faces toward the head, laterally, and slightly dorsally; the sternal part faces laterally. The two parts are sometimes sharply separated by an oblique line which begins at the angle on the caudal border and passes ventrally to the cephalic border.

The **ventral-cephalic** border (Fig. 96) is emarginate, and has the curvature of the surfaces it separates. It is least distinct in the middle region of the rib, but at the vertebral end, and especially at the sternal end, it is distinct and sharp. It gives attachment to the intercostal muscles.

The **dorsal-caudal** border is arcuate. It begins at the tubercle, in an elevated line which ends at the angle in the prominence for muscular attachment. The border then becomes rounded and not definitely marked as far as the sternal third, where it is sharp and distinct. In its vertebral part it faces laterally, dorsally, and slightly toward the tail; in the middle, laterally; and in the sternal part, toward the tail and slightly laterally.

The **sternal extremity** of the rib is squarely truncated. It presents an elongated oval **terminal surface**, which is excavated to receive the dorsal end of the costal cartilage.

The **COSTAL CARTILAGE** is a curved rod about half as long as the rib and much more delicate. From the dorsal to the ventral end it is curved in two directions, toward the head and also medially, thus making a decided rounded angle with the direction of the rib. Its ends are compressed, the dorsal end in a latero-medial direction, the ventral or sternal end in a cephalo-caudal direction. The dorsal end fits into the end of the rib, and the ventral end presents a dorsal and a ventral enlargement, which join the small tubercles on the contiguous ends of the lateral surfaces of the fourth and fifth sternebrae.

The ribs increase in length from the first to the ninth inclusive. The tenth is equal to the ninth. The last three are progressively shorter. They also increase in dorso-ventral curvature from the first to the tenth, and then become straighter.

The cephalic ribs are placed more vertically than the others, which slope ventrally and toward the tail. The cephalic ribs lie in vertical planes which intersect the median vertical plane of the thorax almost at right angles. The planes of the middle and caudal ribs intersect the vertical plane of the thorax in acute angles; in the last ribs these angles do not measure more than thirty degrees. In other words, the heads of the cephalic ribs are directed toward the median line of the vertebral column, while the heads of the middle and caudal ribs gradually become directed more toward

the head than toward the median line. In this way it is that while the ribs increase in length and, to some extent, in the degree of dorso-ventral curvature, the thorax increases in dorso-ventral depth, but only slightly in transverse width. It must be remembered that the positions of the ribs vary in respiration and with the motions of the trunk and limbs.

#### SPECIAL CHARACTERS OF THE DIFFERENT RIBS.

The **First Rib** (Fig. 97) is the shortest, and, relatively to its length, the stoutest. It is less curved, and presents no distinct angle. It is also less flattened, its surfaces and borders being more rounded. It is hardly twisted on its long axis.

The **head** is large, and, since it fits into a single articular facet on the body of the first thoracic vertebra, its articular surface is not divided by a crest and pit into two facets. The **neck** is long and stout, and forms an angle of more than forty-five degrees with the vertebral part of the body; the **tubercle** is very high. Its articular facet faces dorsally and medially, and, while convex from the cephalic to the caudal edge, is flat from side to side. The terminal surface for the costal cartilage is circular.

The **Second Rib** (Fig. 97) may be distinguished from the first by its greater size and its flatter and more twisted form.

The **head** is smaller, and its articular surface is divided by the crest and pit into two facets. The **neck** is more slender. The tubercle is smaller and less prominent, and its articular surface is not so decidedly convex from the cephalic to the caudal edge, and is faintly concave from side to side. There is an **angle**, two or three millimetres below the tubercle. The surface for the costal cartilage is oval.

The **Third Rib** (Fig. 97) is about a fourth longer and considerably wider than the second rib. It is more strongly bowed, and is twisted to a greater degree on its long axis.

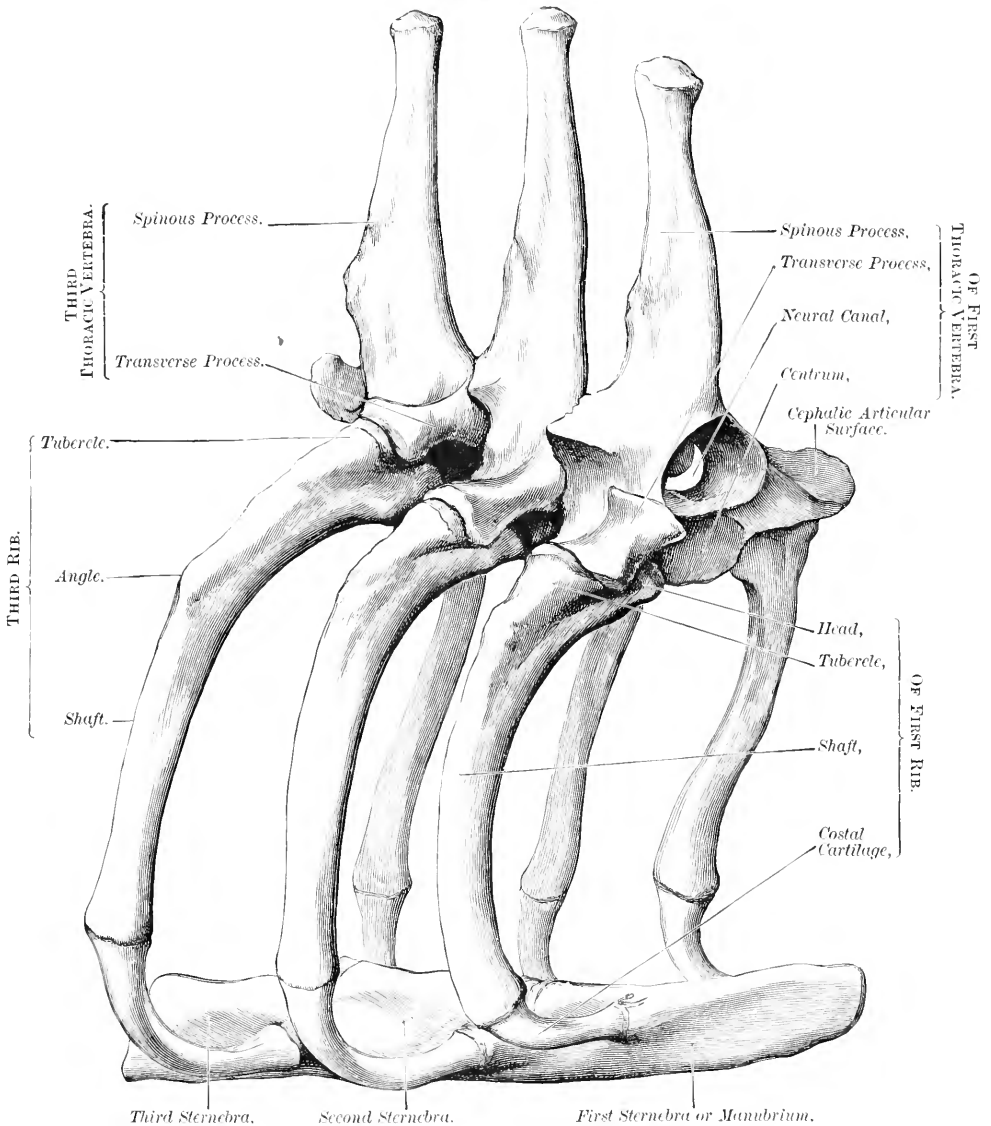
The **head** is not so spherical. The **neck** is stouter and less excavated on the dorsal surface. The **tubercle** is lower, and its articular surface is small and oval. The **angle** of the rib is pronounced. The sternal end is compressed, so that its terminal surface is a long oval.

The **Fourth Rib** (Fig. 98) is a fourth longer than the third, and a trifle more slender. Its dorso-ventral curvature is greater, and its sternal end bends slightly toward the tail.



The head is larger. The tubercle is lower, but larger, and its articular surface is convex from the cephalic to the caudal edge and concave transversely. The angle is distinct and more ventral than in the preceding rib.

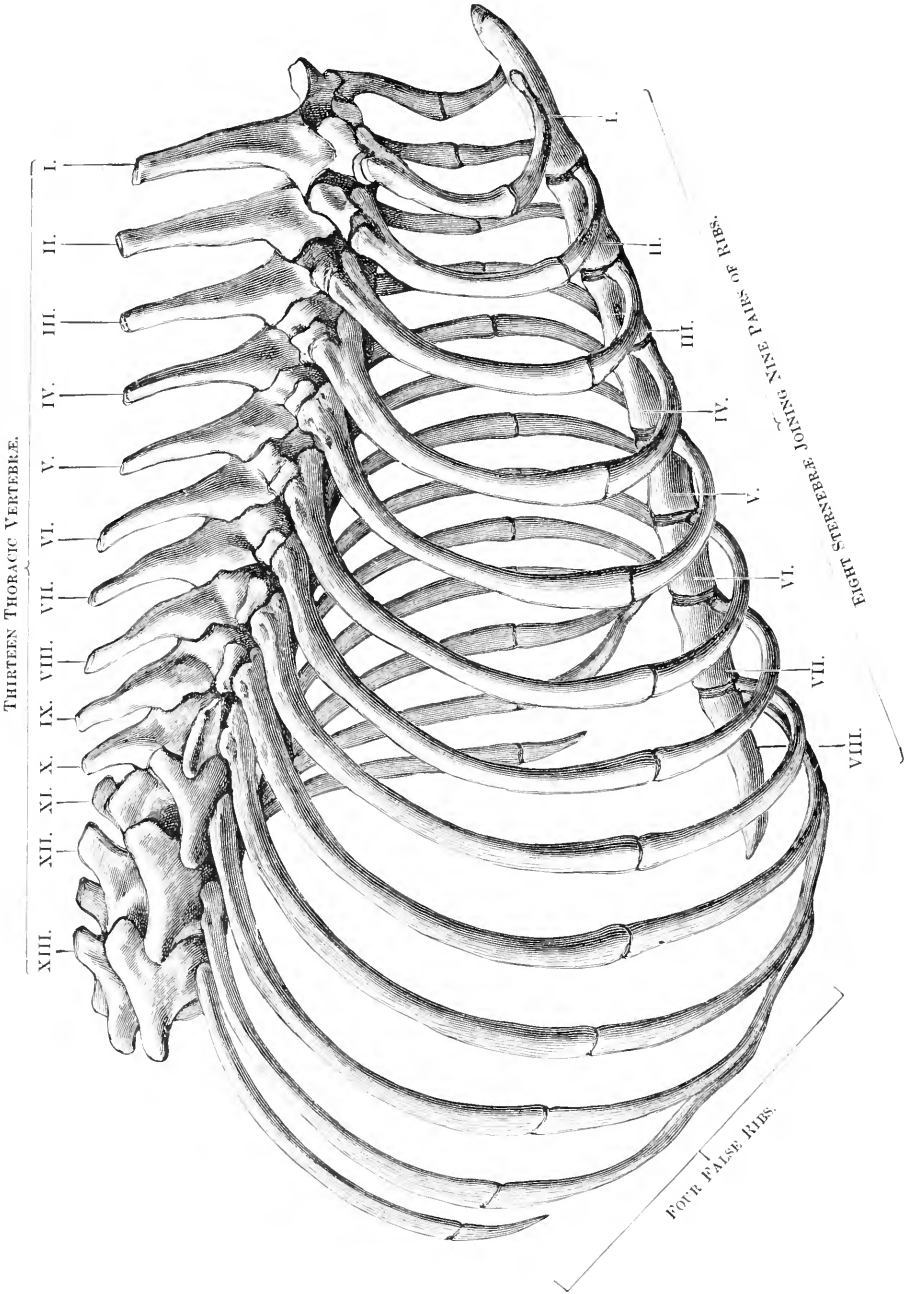
FIG. 97.



CEPHALIC END OF THORAX. THREE THORACIC VERTEBRÆ, THREE PAIRS OF RIBS, AND THREE STERNEBRÆ.

The Fifth and Sixth Ribs (Fig. 98) differ from the fourth and from each other merely in size. The fifth is a fifth longer than the fourth, no stouter, and the sternal end has a more decided curve toward the tail. The sixth is about a seventh longer than the fifth, but rounded and more slender.

FIG. 98.



THE THORAX. RIGHT SIDE VIEWED OBLIQUELY FROM IN FRONT AND ABOVE. (Natural size.)

The **Seventh**, the **Eighth**, the **Ninth**, and the **Tenth** (Fig. 98) are the long, slender ribs. They can be distinguished from all that precede them by their length and slenderness and by their small sternal extremity, the terminal surface of which is almost circular. They differ from the eleventh rib in possessing a **tubercle** articulating with the vertebral transverse process. They have large, pointed **heads** deeply pitted on the articular surface, short **necks** with a broad ventral surface, and a dorsal surface which is gradually encroached upon by the tubercular articular surface. The seventh is a tenth longer than the sixth, the eighth not quite an eleventh longer than the seventh, and the ninth not quite a twelfth longer than the eighth. The tenth is of about the same length as the ninth, or a little shorter.

The **Eleventh**, **Twelfth**, and **Thirteenth** Ribs (Fig. 98) are easily distinguished from all the rest; they are long, very slender, and have rounded, sloping **heads** which are not divided by a pit into two facets; they have no necks and no tubercles. Of the three, the eleventh is the longest and the thirteenth the shortest.

#### RECAPITULATION OF THE CHARACTERS OF THE RIBS.

The **head** presents few changes throughout the series. In the first rib and the last three the articular surface is single and undivided. In the cephalic ribs the head is more rounded, in the caudal it is pointed, and the dorsal surface slopes in a ventral direction to the point.

The **neck** forms a greater angle with the shaft in the cephalic than in the caudal ribs. The cephalo-caudal diameter of the ventral surface is greater in the caudal than in the cephalic ribs.

The **tubercle** is present on all the ribs except on the last three. It is highest and most decidedly separated from the neck in the first two. From the second to the eleventh it becomes gradually lower and continuous with the neck. Beginning with the fifth rib, its lateral edge is sharp and prominent and separated from the dorsal-caudal border of the shaft by a depression for ligamentous insertion. The articular surface on the tubercle of the first rib is quadrate, with its cephalo-caudal diameter the larger, and is almost flat from the lateral to the medial edge. On the second rib it is much smaller, transversely oval, and faintly concave. From the second to the eleventh it increases in size and turns more to the caudal aspect of the bone. From the first

to the fifth it is oval, on the fifth and sixth circular, at the seventh it begins to be oval again and to extend upon the neck of the rib, and when the tenth is reached it has become oblong or pear-shaped, and almost touches the head.

The **shaft** is straighter in the first two and more curved in all the rest. It is more cylindrical in the first rib, and the terminal surface on the sternal end is almost circular; from the second to the eighth the sternal part of the shaft is flattened, and the terminal surface is transversely narrow; from the eighth to the end of the series the body of the rib is more cylindrical, and the terminal surface on the sternal end is less oval and more circular.

The **angle** of the rib is absent from the first, and is well marked from the second to the sixth. A secondary tubercle at the lower end of the superior crest of the rib and above the angle appears on old, strongly developed ribs from the fourth to the eleventh. The tubercle for the attachment of the slips from the erector spinæ muscle marks approximately the angle, and is present in old bones from the second to the seventh inclusive.

**Nomenclature.**—The Latin for rib is *costa*; the German, *die Rippe*; the French, *le côté*.

**Determination.**—The head is on the vertebral end; the tubercle is on the dorsal border, and its articular surface faces to a greater extent toward the tail than toward the head. Therefore, if the head be held upward and the concavity of the rib toward the student, the articular surface of the tubercle and the inner surface of the body will be on the side, either right or left, to which the bone belongs.

**Muscular Attachments.**—The following are the principal muscles attached to the ribs:

The **serratus magnus**, to the cephalic-lateral surface of the first nine ribs, at, or dorsal to, the junction of the rib and the cartilage; the **scalenes**, to the cephalic-lateral surface of the first rib, and to the ventral-cephalic border of the third, fifth, seventh, and eighth ribs, near the serratus magnus; the **external oblique**, to the cephalic-lateral surface of the last nine ribs (on the fifth to the ninth just dorsal to the attachment of the serratus magnus; on the tenth to the thirteenth progressively, more dorsal); the **internal oblique**, to the dorsal-caudal border of the last five ribs; the **transversalis**, to the medial surface of the last five costal cartilages; the **serratus posticus**,

to the cephalic-lateral surface ventral to the angle: (*a*) cephalic division (anterior) on the second to the ninth rib, inclusive; (*b*) caudal division (posterior) on the tenth to the thirteenth rib; the ilio-costal and accessory ilio-costal, to the angles; the longissimus dorsi, to the dorsal-caudal border, lateral to the tubercle; the external and internal intercostals, to the borders; the levatores costarum, to the dorsal-caudal border near the tubercle; the sternalis, to the lateral surface of the first seven costal cartilages; the rectus abdominis, to the ventral part of the cephalic-lateral surface of the first rib and costal cartilage; the infracostals, to the medial surface near the angles; the diaphragm, to the caudal border and medial surface of the last five costal cartilages; and the triangularis sterni, to the medial surface of the costal cartilages from the second to the eighth, inclusive.

**Blood-Supply.**—The ribs are supplied with blood by small branches from the intercostal arteries.

**Ossification.**—Each rib is developed from two principal centres of ossification,—one for the shaft and one for the head. The anterior ten ribs each have a small additional centre for the tubercle.

#### TABLE.

Tubercle, with articular facet, present.

Head with single facet.

High tubercle. The shortest rib; very straight . . . 1

Head with two facets.

Sternal end of body with great cephalo-caudal diameter.

Rib very straight, tubercular facet small . . . 2

Rib more curved, tubercular facet larger, and cir-

cular. Length regularly increases . . . 3, 4, 5, 6

Sternal end of body smaller, more rounded. Tubercular facet oval, continued inward on neck.

Length gradually increases . . . . . 7, 8, 9

Length the same or decreases . . . . . 10

No tubercle with articular facet.

Head with single facet.

Length and degree of curvature decrease gradually . 11, 12, 13

VARIATIONS IN RIBS.

VARIATIONS IN SIZE AND DEVELOPMENT.

The size and degree of development of the ribs are, of course, largely dependent upon the size and strength of the entire skeleton. Within comparatively narrow limits a rib may, however, exhibit variations which are apparently entirely independent of the size of the animal. The fifth rib, for example, is always longer than the fourth and shorter than the sixth, but the degree of increase or decrease in its length is by no means constant.

The following table shows the size of the ribs of nine specimens. The measurements were made by placing the rib on a card ruled in square millimetres, with the caudal aspect uppermost and the curvature away from the observer; the length (L) represents the extreme distance on a straight line from the vertebral to the sternal end; the degree of curvature (C) is the shortest distance from this line to the point of maximum convexity wherever that falls on the concave side of the rib. It is probable that the relation between the curvature and the length is to some extent dependent upon the effects of drying after maceration. The width (W) is the greatest diameter of the sternal end of the bony rib.

Specimen No.		1	2	3	4	5	6	7	8	9	
Rib 1	L.	{ R.	25	24	23	23	22	22	21	24	17
		{ L.	25	25	23	23	23	23	21	23	17
	C.	{ R.	7	5	5	5	6	6	4	5	5
		{ L.	7	5	5	5	5	6	4	5	5
	W.	{ R.	5	5	4	4.5	4	4	4.5	4	4
		{ L.	5	5	4	4.5	4	4	4.5	4	4
Rib 2	L.	{ R.	29	29	28	25	27	26	24	29	22
		{ L.	29	29	28	27	27	25	25	29	22
	C.	{ R.	6	5	5	5	6	5	4	5	6
		{ L.	6	6	5	5	5	6	4	5	6
	W.	{ R.	4	4	3	3	4	3.5	3	4	3
		{ L.	4	4	3	3	4	3	3.5	4	3
Rib 3	L.	{ R.	34	34	33	30	32	31	31	35	27
		{ L.	35	35	34	31	33	31	31	35	27
	C.	{ R.	8	7	7	7	9	6.5	5	6	7
		{ L.	8	7	8	6	7	6	5	6	7
	W.	{ R.	4	4	4	4	4.5	4	4.5	4	3
		{ L.	4	4	4	4	4	4	4	4	4
Rib 4	L.	{ R.	41	41	40	35	40	36	37	41	31
		{ L.	42	41	40	36	41	37	37	42	32
	C.	{ R.	11	10	9	9	10	9	7	8	9
		{ L.	11	10	9	8	10	9	7	8	9
	W.	{ R.	4.5	4	4	4	5	4	4.5	5	4
		{ L.	4.5	4	4	4	5	3.5	4	5	4

Specimen No.			1	2	3	4	5	6	7	8	9
Rib 5	L.	R.	49	48	46	40	48	42	42	48	36
		L.	49	49	46	42	48	43	42	49	37
	C.	R.	13	12	11	10	12	10	9	11	10
		L.	13	12	11	10	12	11	9	10	10
	W.	R.	5	5	4	5	5	4	4.5	5	4
		L.	5	5	4	4.5	5	4	4.5	5	4
Rib 6	L.	R.	55	54	53	46	54	49	47	55	42
		L.	56	55	52	47	55	49	47	55	42
	C.	R.	15	13	12	12	13	11	12	12	11
		L.	14	13	12	11	13	12	12	12	11
	W.	R.	5	5	4	5	5	5	4.5	5	4
		L.	5	5	3	4.5	5	5	4.5	...	...
Rib 7	L.	R.	63	60	59	52	60	54	50	60	46
		L.	64	61	59	52	60	54	50	60	46
	C.	R.	16	14	13	12	15	12	13	14	12
		L.	15	15	14	12	14	12	13	14	12
	W.	R.	4	5	3	4	5	4	4	4	3.5
		L.	4	4.5	3	4	5	4	5	4	3.5
Rib 8	L.	R.	68	64	64	58	65	58	53	65	50
		L.	68	65	60	58	65	58	53	64	50
	C.	R.	16	16	15	13	16	14	15	15	13
		L.	16	16	15	13	15	13	15	15	13
	W.	R.	4	4	3	3.5	4	3.5	3.5	4	...
		L.	4	4	3	3.5	4	3.5	3.5	4	3.5
Rib 9	L.	R.	70	69	...	62	68	64	54	68	52
		L.	71	70	67	62	68	64	54	67	52
	C.	R.	16	16	...	14	15	15	15	15	14
		L.	17	16	15	14	16	14	15	16	14
	W.	R.	4	3.5	...	3	3.5	3	3.5	4	3
		L.	4	3.5	3	3.5	3.5	4	4	3.5	3
Rib 10	L.	R.	70	68	64	62	68	62	53	67	51
		L.	70	68	65	62	67	63	52	66	52
	C.	R.	17	17	14	13	16	15	15	15	14
		L.	17	16	15	13	16	14	15	15	14
	W.	R.	3.5	4	3	3	3.5	3	3.5	4	3
		L.	4	4	3	3.5	3.5	3	4	3.5	3
Rib 11	L.	R.	66	64	55	61	64	60	49	62	48
		L.	66	64	58	60	64	61	50	61	50
	C.	R.	17	16	15	12	15	15	13	13	12
		L.	17	16	14	13	16	13	13	13	12
	W.	R.	3	3	3	3.5	3.5	3	3.5	3.5	3
		L.	3.5	3	3	3.5	2.5	3	4	3.5	3
Rib 12	L.	R.	63	60	50	56	59	54	45	57	45
		L.	62	60	53	55	60	55	46	56	...
	C.	R.	13	13	13	11	14	12	9	11	10
		L.	13	13	12	12	14	11	9	11	...
	W.	R.	3	2.5	3	2.5	2.5	3	3	3	3
		L.	3	2.5	2.5	2.5	2.5	3	3	3	...
Rib 13	L.	R.	56	52	43	51	54	47	41	49	41
		L.	56	53	45	51	55	47	41	48	41
	C.	R.	9	8	6	9	10	9	5	7	7
		L.	9	8	6	10	9	7	5	7	9
	W.	R.	2.5	2	1	2	2	2.5	2	2.5	2
		L.	3	2	2.5	2	2	2.5	2	2.5	2
Rib 14	W.	L.	...	...	...	...	44	...	...	...	...
		Vertebral	...	...	...	...	4	...	...	...	...
		Sternal	...	...	...	...	1	...	...	...	...

The ribs are subject to marked variations in the development of their peculiar features. In some specimens the surfaces are deeply impressed by muscular attachments, and the prominent borders develop accessory angles; in other specimens a few leading features only are distinguishable, all others have disappeared.

The eleventh rib frequently exhibits a tubercle, more or less marked, which articulates with a rudimentary vertebral transverse process (Figs. 54, 55). This variation is independent of variations in the number of the ribs.

In one specimen of very many examined, the vertebral part of the caudal-medial surface of the tenth rib is deeply grooved for the intercostal vessels; an interesting variation, because it reproduces a normal feature of the human ribs.

In another specimen the heads of the twelfth and thirteenth ribs of both sides have a distinct vertebral surface deeply grooved transversely to the long axis of the rib. Inasmuch as the articular facets on the corresponding vertebræ exhibit no peculiarities, the groove probably transmitted tendons or vessels.

#### VARIATIONS IN NUMBER.

The number of ribs may be increased to fourteen by the addition of a pair attached to the first lumbar vertebra. In the one example of this variation which I have preserved (No. 5 in the table), the additional ribs resemble enlarged and somewhat modified lumbar transverse processes rather than true ribs; they are not round, but flattened, especially at the vertebral end, which is four times as wide as the free end; they are not bowed, but exhibit merely a faint sinuous cephalo-caudal curve.

The occurrence of cervical ribs attached to the seventh cervical vertebra is not very rare in man, but so far as known they do not occur in the cat. This is not surprising, because the seventh cervical vertebra normally lacks the arterial canal and the costal element in its transverse process, features which we should expect to find permanently developed before the cervical ribs appear.

So far as known, the number of ribs in the cat is never less than thirteen pairs; the thirteenth pair, however, are sometimes so greatly reduced in size that their entire absence would not be remarkable.

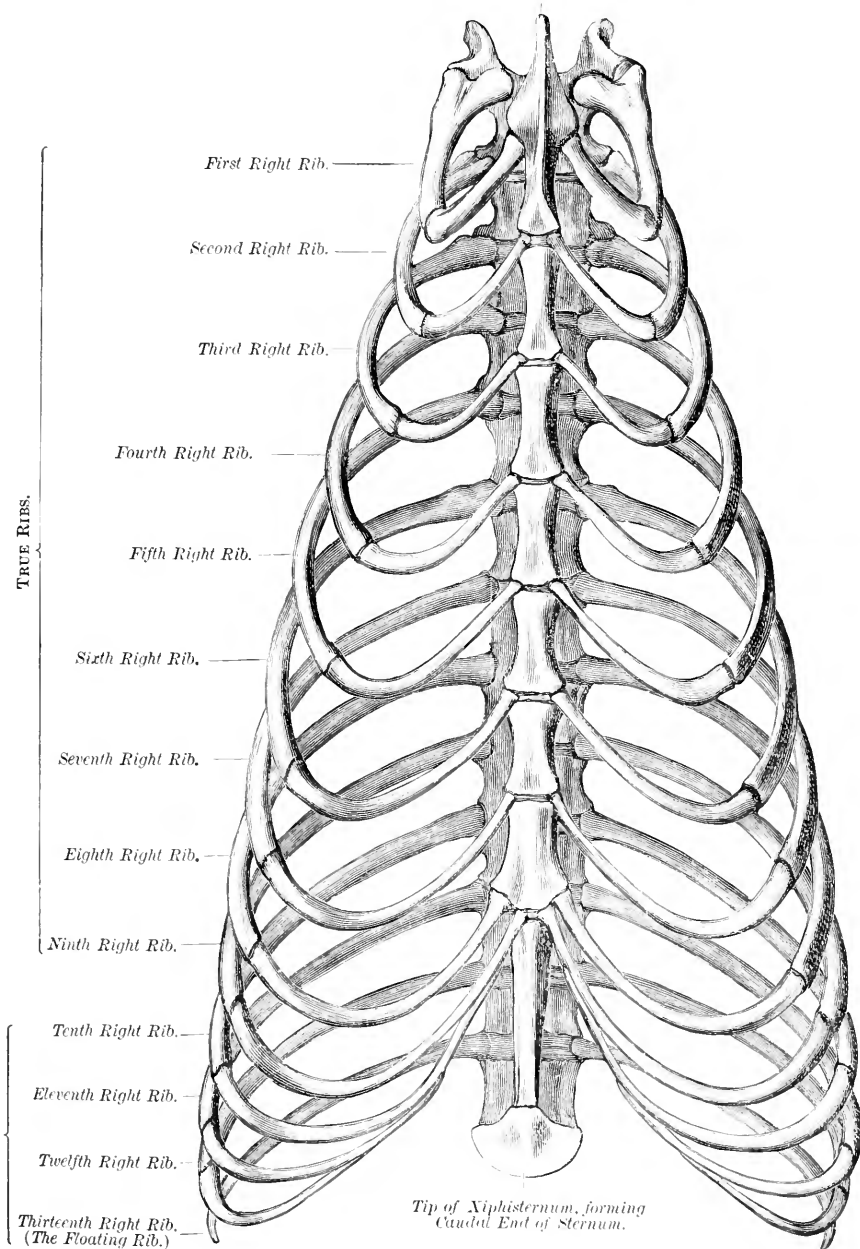


## THE STERNUM.

The Sternum (Figs. 98, 99) is the long, jointed, cylindrical rod which lies in the ventral middle line of the body opposite the thoracic

FIG. 99.

*Manubrium, forming Cephalic End of Sternum.*



THE THORAX, VENTRAL ASPECT. (Natural size.)

region of the vertebral column. It forms the median portion of the ventral wall of the thorax by furnishing attachment along its sides to

the ventral ends of the cartilages of the ribs. It is separated from the vertebral column by the entire dorso-ventral diameter of the thorax. Owing to the conical shape of the thorax, this diameter is small at the cephalic end and large at the caudal end, and the cephalic end of the sternum is therefore much closer to the vertebral column than is the caudal end. For example: if it is distant from the vertebral column at the cephalic end by twenty millimetres, it is distant at the caudal end by at least one hundred and ten millimetres. The sternum has an oblique position in the body, and is directed from the cephalic end ventrally and toward the tail. Since the sternum moves with the ribs back and forth in respiration and in muscular efforts, it does not always lie ventral to the same vertebræ. It appears to reach from a point ventral to the fifth cervical to a point ventral to the twelfth dorsal. The sternum can be felt lying in a groove between the heavy pectoral muscles which rise in part from its ventral surface.

The sternum is composed of eight oblong bones, called *sternebræ*. They are arranged end to end, and are united by plates of cartilage. These cartilages are large in young animals, and their sides furnish most of the attachment for the costal cartilages. In fully developed sterna the cartilages are thin disks and the ribs are fastened also to the adjoining sides of the *sternebræ*. The *sternebræ*, with the exception of the first and the eighth, are similar in shape and vary little in size. In a typical one the length is about three times the width, which is

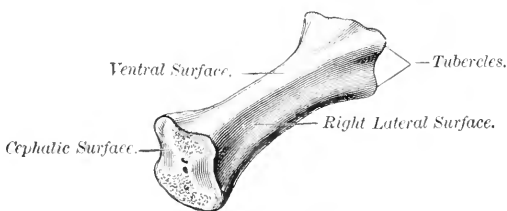
equal to the height. There are six surfaces: the anterior or cephalic, the posterior or caudal, the dorsal, the ventral, and the two lateral.

The **cephalic** and **caudal surfaces** are quadrilateral. The lateral margins are emarginate, and the dorsal and ventral margins gently arcuate.

The **cephalic surface** (Fig. 100) has the dorso-ventral diameter greater than the transverse diameter, but in the caudal surface (Fig. 101) the two diameters are about equal.

The **lateral surfaces** are much longer than wide. The cephalic and caudal margins are straight. The dorsal and ventral margins are

FIG. 100.

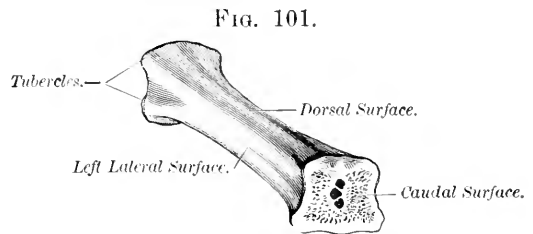


TYPICAL STERNEBRA, VENTRAL VIEW.

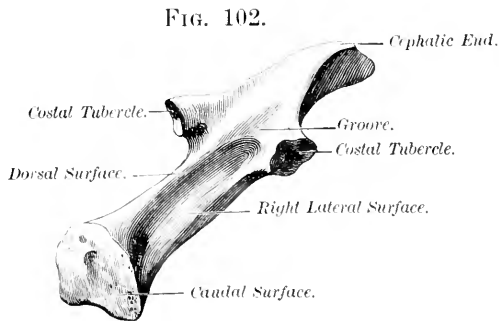
straight or faintly emarginate. Each lateral surface presents at the cephalic and caudal ends a dorsal and a ventral tubercle, separated by a narrow longitudinal groove. To these tubercles, which are well developed in old animals, is attached the bifurcated sternal end of a costal cartilage. Between the two sets of tubercles the lateral surface is gently concave along its cephalo-caudal diameter, and, for the most part, dorso-ventrally flat.

The dorsal and ventral surfaces closely resemble each other, and also resemble the lateral surfaces. They differ from the lateral surfaces usually in being narrower and more or less constricted in the middle, and in not possessing the cephalic and caudal tubercles. The ventral surface (Fig. 100) is narrower and more convex at the cephalic than at the caudal end, while in the dorsal surface (Fig. 101) the two ends are more nearly equal, although the caudal always exceeds the cephalic.

The First Sternebra (Fig. 102) is called the **manubrium**<sup>1</sup> or **pre-sternum**. It is nearly twice as long as the average sternebra, and,



TYPICAL STERNEBRA, DORSAL VIEW.



MANUBRIUM OF STERNUM. VIEWED FROM ABOVE, BEHIND, AND THE RIGHT SIDE.

although a little higher, it is much narrower. Its cephalic end is compressed from side to side and rounded at the tip. The ventral surface (Fig. 99) is raised in the middle line into a rounded keel. A little cephalic to the middle each lateral surface is prolonged into a

<sup>1</sup> A handle.

triangular flattened process, to the concave caudal margin of which the end of the first costal cartilage is attached. The dorsal surface (Fig. 102) is concave on a cephalo-caudal line and convex transversely. A faint groove separates the process from the body of the bone.

The Eighth Sternebra (Fig. 99) is called the **xiphisternum** or **metasternum**. It is longer than the manubrium, and the length is still further increased by a fan-shaped terminal cartilage known as the **xiphoid**<sup>1</sup> or **ensiform**<sup>1</sup> cartilage. The bony portion of the xiphisternum is cylindrical, narrow at the caudal end. It is the most movable portion of the sternum, and does not furnish attachment to any of the costal cartilages. It is joined to the seventh sternebra by a quadrate piece of cartilage the sides of which are more or less related to the attachment of the costal cartilages of the eighth and ninth ribs.

The remaining sternebrae constitute the **mesosternum**. They decrease gradually in length until the seventh is reached, which is one-fourth shorter than the second, which in turn is two-fifths shorter than the manubrium. They do not decrease in breadth; indeed, the fifth, sixth, and seventh are actually wider. In the second and third the ventral surface is distinctly narrowed in front. In the seventh sternebra of adult animals each lateral surface is raised at the caudal end into a process which joins the eighth costal cartilage, the caudal surface presenting on each side of the point of union of the xiphisternum a facet for the end of the ninth costal cartilage.

The length of the entire sternum is twenty times greater than its average width.

**Nomenclature.**—Sternum is from the Greek *sternon*, the breast. As used by Homer, it always refers to the male breast, *stethos* (whence stethoscope) referring to the breast of either sex. Galen employs *thorax* for the breast, and first used *sternon* for the breast-bone. Sternum is derived from *stercos*, hard, because, owing to the absence of muscular covering, it is hard when felt through the skin.

**Muscular Attachments.**—The sternum affords attachment to the following muscles: the **sternomastoid** and the **sternohyoid**, to the manubrium; the **pectoral**, to the ventral surface; the **triangularis sterni**, to the dorsal surface; and the **diaphragm**, to the xiphisternum.

<sup>1</sup> *Xiphos* (Gr.), *ensis*, a sword.

**Ossification.**—Each sternebra appears to be developed from a single centre of ossification; but there is ground for believing that these centres are derived from paired primary centres.

#### VARIATIONS IN THE STERNEBRÆ.

##### VARIATIONS IN SIZE AND DEVELOPMENT.

The size of the entire sternum is largely dependent upon the size of the animal; it is influenced, however, to a great extent by the size of its variable terminal xiphisternum.

The following table exhibits the maximum lengths and widths of the sternebræ in ten skeletons. The measurements are given in millimetres, and do not include the intersternbral cartilages.

Specimen No.		1	2	3	4	5	6	7	8	9	10
1, or Manubrium	L.	24	24	22	22	22	22	22	21	20	18
	W.	9	9	9	8	8	8	6	8	8	8
2	L.	16	15	14	13	12	15	13	12	12	14
	W.	6	5	5	5	4.5	6	4	4	4	4
3	L.	14	14	13	13	14	14	13	12	13	13
	W.	6	5	5	5	5	6	5	5	5	5
4	L.	14	14	13	12	13	13	13	12	12	12
	W.	7	6	6	6	5	6	5	6	5	5
5	L.	13	14	12	12	12	13	12	12	12	12
	W.	7	7	7	6	6	6	5	6	5	5
6	L.	13	14	11	12	12	11	12	11	11	11
	W.	7	7	7	7	6	6	5	6.5	5	6
7	L.	13	14	8	7	11	10	Absent	11	10	9
	W.	7	10	7	7	7	7		7	5	6
8, or Xiphisternum	L.	22	25	22	21	23	20	22	21	17	23
	W.	6	7	5	6	6	5	5	4	4	5

As a rule, the sternebræ are regular and symmetrical; some variability in form is frequently shown by the seventh and by the xiphisternum.

##### VARIATIONS IN NUMBER.

The number of sternebræ may be increased to nine by the addition of a short cubical element between the seventh and the xiphisternum. In some sterna this abnormal eighth piece is so far reduced in size

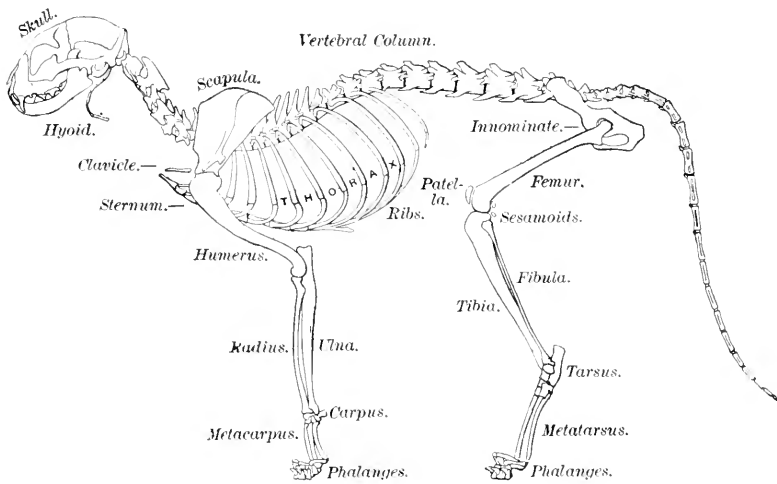
that it does not reach the surface of the sternum, and hence may be easily overlooked.

I have one specimen (No. 7 in the table) in which the number of sternebrae is reduced to seven, apparently by the total absence of the normal seventh, the sixth and eighth retaining their usual relative proportions.

### THE THORAX.

The Thorax (Fig. 103) occupies the cephalic part of the trunk, and encloses, supports, and protects the heart and great blood-vessels, the lungs, and to some extent also the abdominal viscera. To its sides at the cephalic end are attached the thoracic limbs, and the rest of

FIG. 103.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

its outer surface gives origin and insertion to important muscles of the trunk and limbs.

The bony thorax is a conical, cage-like structure, composed principally of the twenty-six ribs and their costal cartilages, held together at their dorsal ends by the thirteen thoracic vertebrae and at their ventral ends by the eight sternebrae.

The thorax is entirely filled by the viscera; its walls are everywhere completely closed by muscles and membranes, and its cephalic and caudal ends are shut off from the neck and abdomen, except to give entrance and exit to the alimentary and respiratory passages and to the blood-vessels and nerves; but the thorax which has been stripped of all its soft parts presents a very different appearance. It has a

quadrate cephalic opening or **inlet**, a very much larger, more circular caudal opening or **outlet**, and the walls exhibit long, wide slits between the ribs. As each of these intercostal spaces is about four times as wide as the ribs which bound it, only one-fourth of the walls of the thorax may be said to be composed of bone.

The thorax presents for examination an inlet and an outlet, dorsal, ventral, and lateral walls, and a cavity.

The **inlet** or cephalic opening of the thorax (Fig. 97) is bounded ventrally by the manubrium, or first sternebra, and the first pair of costal cartilages; at the sides, by the shafts of the first pair of ribs; and dorsally, by the necks and heads of the ribs and the ventral surface of the first thoracic vertebra. Its sides are almost vertical, arching somewhat away from the middle line. Its dorso-ventral diameter is but a trifle greater than the transverse diameter; its outline therefore is almost square. Its plane faces toward the head and to a varying degree dorsally.

The **outlet** or caudal opening of the thorax (Figs. 98, 103) has the outline of an ellipse the long axis of which is vertical. It is bounded ventrally by the last sternebra and the united costal cartilages of the ribs, and at each side by the overlapping costal cartilages of the eleventh and twelfth ribs, by the ventral end of the twelfth rib and the entire length of the thirteenth rib, the dorsal end of which, with the body of the thirteenth thoracic vertebra, completes the dorsal outline. It is difficult to give accurate measurements to the outlet of the thorax, owing to the changes which it undergoes during life in respiration and in other muscular movements, and after death by the drying and fixation of the caudal ribs and costal cartilages. From the study of transverse sections and plaster casts, the outlet appears to be a third higher than wide. The plane of the opening is not flat, but bent at a sharp angle in its dorsal quarter, since from the sternum to the ends of the thirteenth ribs it is directed dorsally and toward the tail and from the ends of the thirteenth ribs to the vertebra it is directed dorsally and toward the head.

The **dorsal wall** of the thorax presents a median longitudinal ridge, formed by the prominent bodies of the thoracic vertebrae. On each side of this ridge is a wide longitudinal furrow, produced by the arching dorsally of the dorsal ends of the ribs. When the animal is standing or walking the dorsal wall is not horizontal, but is directed

from the cephalic end toward the tail and dorsally. It is not perfectly straight, but follows the curves of the vertebral column, and is at first convex and then slightly concave ventrally.

The **ventral wall** of the thorax is shorter than the dorsal wall. It is formed by the sternum and the costal cartilages. It is triangular, almost pointed, at the cephalic end, and curves dorsally into the walls where the thorax is widest at the caudal end. It is almost flat at first, but gradually becomes more convex transversely as it passes toward the tail. It is directed from the cephalic end ventrally and toward the tail, and extends from a point ventral to the sixth cervical vertebra to a point ventral to the junction of the bodies of the eleventh and twelfth thoracic vertebrae; but, of course, as this position is varied in life, the one given may not be the one found after death.

The **lateral walls** of the thorax arch dorso-ventrally and laterally, more strongly at the caudal than at the cephalic end, and are directed from the inlet toward the tail and laterally. Their dorso-ventral height increases from the cephalic end to a point ventral to the tenth thoracic vertebra, whence it decreases rapidly, owing to the obliquity of the plane of the outlet. The walls are formed of the ribs and the dorsal part of the costal cartilages. The first two or three pairs of ribs are almost vertical, but the rest are directed from the vertebral end in a curve ventrally and toward the tail, the obliquity increasing in the caudal ribs.

The **cavity** of the bony thorax is conical, compressed from side to side in front, but behind the fifth vertebra the transverse diameter exceeds the vertical. It is a third longer than high at its highest caudal part. It does not always, however, have these dimensions. It is enlarged by the filling of the lungs in inspiration and diminished when the air is driven out in expiration. The enlargement is due principally to the movement of the ribs toward the head and laterally, but also to the movement toward the tail, or the flattening, of the diaphragm,—the muscular sheet which forms a partition between the thoracic and abdominal cavities.

The enlargement of the thorax by the movements of the ribs may be explained as follows. An examination of the articulation of a rib to the vertebra shows that the rib cannot be pulled dorsally or ventrally, nor in a cephalic or a caudal direction, because of the close union between its tubercle and the vertebral transverse process; but



the ball-and-socket joint between the head of the rib and the vertebral bodies and the nature of the facet on the transverse process, whereof the concavity is along a cephalo-caudal line, permit the rotation of the vertebral end of the rib about its own axis. This rotation is effected by muscles passing from the rib to the vertebral column, the other ribs, the sternum, and even to the limbs. In the enlargement of the thorax in inspiration the rotation of the rib is on the arc of a circle toward the tail and ventrally. The movement, small at the vertebral end, becomes greater at the sternal end, especially in the long caudal ribs, which are more loosely joined to the vertebral column. Owing to the curve in the rib and its oblique direction, ventrally and toward the tail, the rotation of its vertebral end moves the sternal end toward the head and ventrally, and thus increases the cephalo-caudal diameter by moving the whole thorax toward the head, at the same time increasing the dorso-ventral diameter of the thorax by bringing the rib more nearly perpendicular. The rotation, finally, turns the convexity of the rib, which—especially in the caudal ribs—faces toward the tail and laterally, directly laterally, and thus increases the transverse diameter of the thorax. As the costal cartilages bend medially, ventrally, and toward the head, they oppose this rotation toward the head and laterally of the ribs, and, when the muscles of inspiration cease to act, return the ribs to their former position, producing the expiration of the air with the minimum expenditure of muscular energy.

#### HUMAN RIBS.

The skeleton of man has twelve pairs of ribs, whereof seven are directly united to the sternum by their cartilages. In three of the remaining five pairs the cartilages turn toward the head and join the caudal borders of their immediate predecessors, and in the last two pairs the ventral ends are free in the muscle of the abdominal wall. Thus there are seven pairs of true ribs and five pairs of false ribs, whereof two pairs are floating ribs. It will be remembered that the cat has nine pairs of true ribs and four pairs of false ribs, whereof one pair only are floating ribs.

#### A TYPICAL HUMAN RIB.

On comparing the fifth rib of man with the corresponding rib of the cat, the student will observe that it has a more decided dorso-

ventral curvature, and that its ventral end has a marked caudal inclination, turning upward when the rib is laid with its cephalic edge upon the table. The shaft is twisted to a greater degree round its long axis, the caudal-medial surface assuming at the sternal end a more caudal direction.

The **head** of the human rib is flatter and bevelled at the expense of the dorsal surface. The caudal (inferior) part of its articular surface is much larger than the cephalic (superior) part.

The **neck** is long, slender, and prismatic. The **tubercle** is relatively smaller; as in the cat's rib, its articular surface faces in a caudal, dorsal, and medial (inferior, inner, and posterior) direction. It is separated laterally by an oblique line from a prominence for the insertion of a costo-transverse ligament.

The **shaft** is prismatic in its vertebral part, but becomes flattened and expanded in its sternal part.

The **cephalic-lateral** (external) **surface** appears as the continuation of the dorsal surface of the neck. It is very slightly convex in its cephalo-caudal width; of course, strongly convex in its dorso-ventral length; more decidedly convex in its vertebral part. It is marked at the **angle** by a short oblique line.

The vertebral part of the **caudal-medial** (internal) **surface** is divided into two areas by an oblique line running from the ventral border of the neck to the dorsal-caudal border. The dorsal triangular area is a **groove** for the intercostal vessels. The ventral area forms part of the inner wall of the thorax, and is slightly convex from the ventral-cephalic to the dorsal-caudal border, and, of course, strongly concave from the vertebral to the sternal end.

The **costal cartilage** is relatively shorter, stouter, and less curved.

#### CHARACTERS OF THE REMAINING HUMAN RIBS.

The ribs increase in length from the first to the seventh or eighth, and then successively decrease to the last. The intermediate ribs are broader and flatter, and their terminal sternal surface is linear.

The **First Rib** is the most curved, the strongest and the shortest, and has the longest neck. It lies for its whole extent nearly in one plane. Its **head** has a single articular facet. The tubercle is high; the shaft has no angle. Its cephalic surface is crossed by two shallow grooves for the subclavian vessels. Between the grooves on

the medial border is an elevation for the attachment of the scalenus anticus muscle. The caudal surface has no groove for the intercostal vessels.

The **Second Rib** is flat, but is longer and narrower than the first. Its shaft is more regularly arched, and has a faint intercostal groove.

The **Tenth Rib** is long and curved, is marked by a deep intercostal groove, and presents but a single articular facet on its head.

The **Eleventh Rib** has no tubercle, only traces of an angle and a groove, and a single facet on the head.

The **Twelfth Rib** has neither tubercle nor groove, and a small, single, capitular facet.

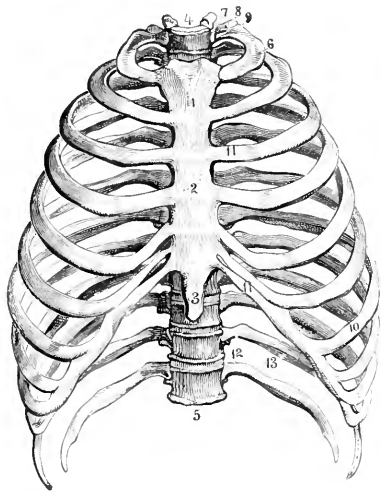
The cartilages of the first three ribs are directed ventrally, those of the remaining ribs ventrally and toward the head. The cartilage of the eighth rib is the longest.

#### HUMAN STERNUM.

The sternum in man (Fig. 104) is a narrow and flat plate which late in life forms a single piece of bone, but before complete coalescence of its parts consists of an hexagonal cephalic piece, the manubrium or pre-sternum; a much longer body, or meso-sternum; and a short terminal ensiform process, or xiphisternum. Its length is about three times as great as its maximum width across the manubrium. It is gently arched ventrally along its cephalo-caudal axis. On each side it affords direct attachment to seven costal cartilages, whereof one is attached to the manubrium, one between the manubrium and the body, four to the body, and one between the body and the ensiform process.

The cephalic border of the **manubrium** presents the median **interclavicular notch**, on each side of which is an oval, saddle-shaped area,—the **clavicular notch** for union with the sternal end of the clavicle. From the caudal end of this notch a

FIG. 104.



FRONT VIEW OF THE THORAX.

1, 2, 3, the three pieces of the sternum; 4, 5, the thoracic vertebrae; 6, the first rib; 7, its head; 8, neck; 9, tubercle; 10, the seventh rib; 11, costal cartilages; 12, the floating ribs; 13, groove for the intercostal blood-vessels.

triangular roughened area extends toward the mesosternum, offering attachment to the cartilage of the first rib. The lateral border of the manubrium then turns sharply and inclines toward the middle line, and ends by meeting the caudal border.

The **mesosternum** is of almost uniform width and thickness. It usually presents on the ventral (anterior) surface a transverse line opposite each costal union, indicating its original separation into four pieces. The lateral border exhibits a half-facet at each end and four intermediate entire facets for the ends of the costal cartilages. The facets for the fifth, sixth, and seventh cartilages are closer together than are the cephalic four. Between the facets the lateral border is distinctly emarginate, forming **intercostal notches**.

The **xiphisternum** is a small, variable piece, usually notched or bifid at the caudal end, and placed in a plane dorsal to the plane of the rest of the sternum. It exhibits at the cephalic end of each lateral border an obscure half-facet for part of the sternal end of the cartilage of the seventh rib.

#### HUMAN THORAX.

The human thorax (Figs. 6, 104) is relatively shorter and wider than the cat's thorax, and its dorso-ventral diameter is relatively smaller. The greater curvature of the ribs renders its walls more regularly arched, and causes the vertebral column to encroach to a greater degree upon the dorsal part of its cavity. The ribs have also a more marked inclination toward the pelvis, which, with their greater width, reduces the width of the intercostal spaces. The **inlet** of the thorax is reniform, with its transverse diameter twice as long as its dorso-ventral.

## CHAPTER IV

## THE SKULL—THE CRANIUM

THE bones of the head are often divided into two groups: (1) those which are closely united to form the **skull**, and (2) those which form the **hyoid** apparatus,—a loosely jointed ventral arch, attached above to the back part of the skull, and supporting, below, the base of the tongue and the larynx. This division, however, is for convenience only; the hyoid bones are parts of the skull, although in man and in some other animals their relation to it is not obvious in the adult condition.

The skull proper is further divided artificially into the cranium and the face.

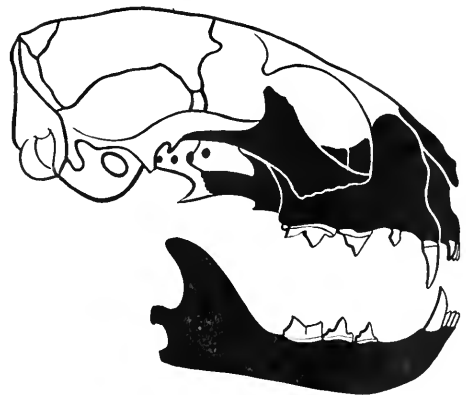
The **cranium** (Fig. 105) comprises the posterior part, which surrounds the brain and articulates behind with the atlas vertebra. It is united to the face in front and below by immovable sutures, but enters into an articulation on each side below with the only movable face-bone, the mandible. To the lower posterior part of the sides of the cranium are attached the superior hyoid bones.

The **face** (Fig. 105) comprises the anterior part of the skull, which surrounds the mouth, or oral cavity. With the anterior part of the cranium it forms the orbital and nasal cavities.

The cranium is composed of ten bones: the occipital, the two temporals, the two parietals, the interparietal, the sphenoid, the two frontals, and the ethmoid.

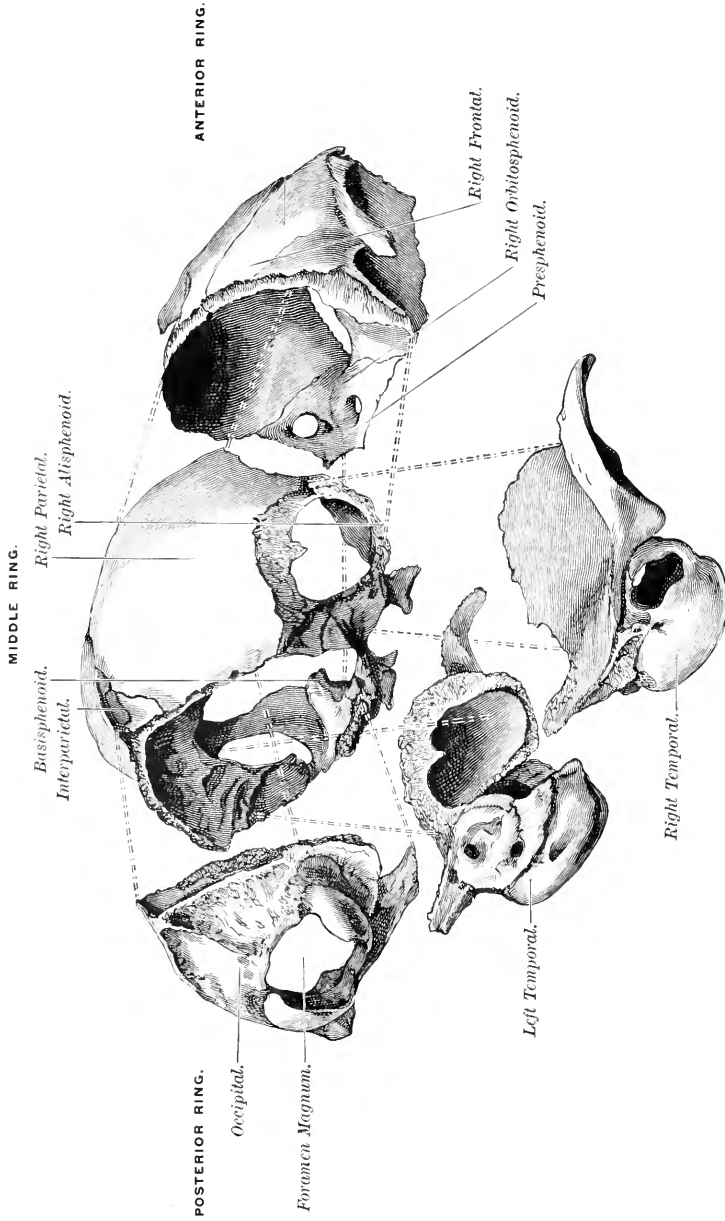
If we remove the ethmoid, which is at the anterior end, almost

FIG. 105.



THE SKULL, LATERAL ASPECT.  
The cranium white, the face black.

FIG. 106.



SIDE VIEW OF ALL THE BONES OF THE CRANIUM, EXCEPT THE ETHMOID, SEPARATED INTO THREE RINGS. The two Temporal Bones removed from Middle Ring and shown below. Dotted lines show manner of articulation. (Natural size.)

entirely contained in the nasal cavity, and hence largely surrounded by the bones of the face, the rest of the cranium can be separated into **three rings** (Fig. 106), whereof each bears a resemblance to a vertebra in that it consists of a basal part (or body) and lateral walls (pedicles and laminae) and includes a greatly enlarged neural cavity.

The flattened **posterior ring** is formed of the occipital bone alone; the foramen magnum represents the neural canal of a vertebra; the basal portion of the bone, known as the basioccipital, represents the body; the lateral portions, known as the exoccipitals, represent the pedicles; and the upper part, the supraoccipital, represents the united laminae.

The **middle ring** is formed of the posterior half of the sphenoid, the temporals, the parietals, and the interparietal. The basal part of the posterior half of the sphenoid, known as the basisphenoid, represents the body of a vertebra, its lateral parts, known as the alisphenoids, with the temporals, represent the pedicles, and the parietals and the interparietal represent the laminae. The neural canal is greatly enlarged, especially above.

The **anterior ring** is formed of the anterior division of the sphenoid with the frontals. The central basal part of this division of the sphenoid, known as the presphenoid, represents the body of a vertebra; the lateral parts, the orbitosphenoids, represent the pedicles, and the frontals represent the laminae. The neural canal is not so large; its anterior opening is closed by the ethmoid, which has been removed.

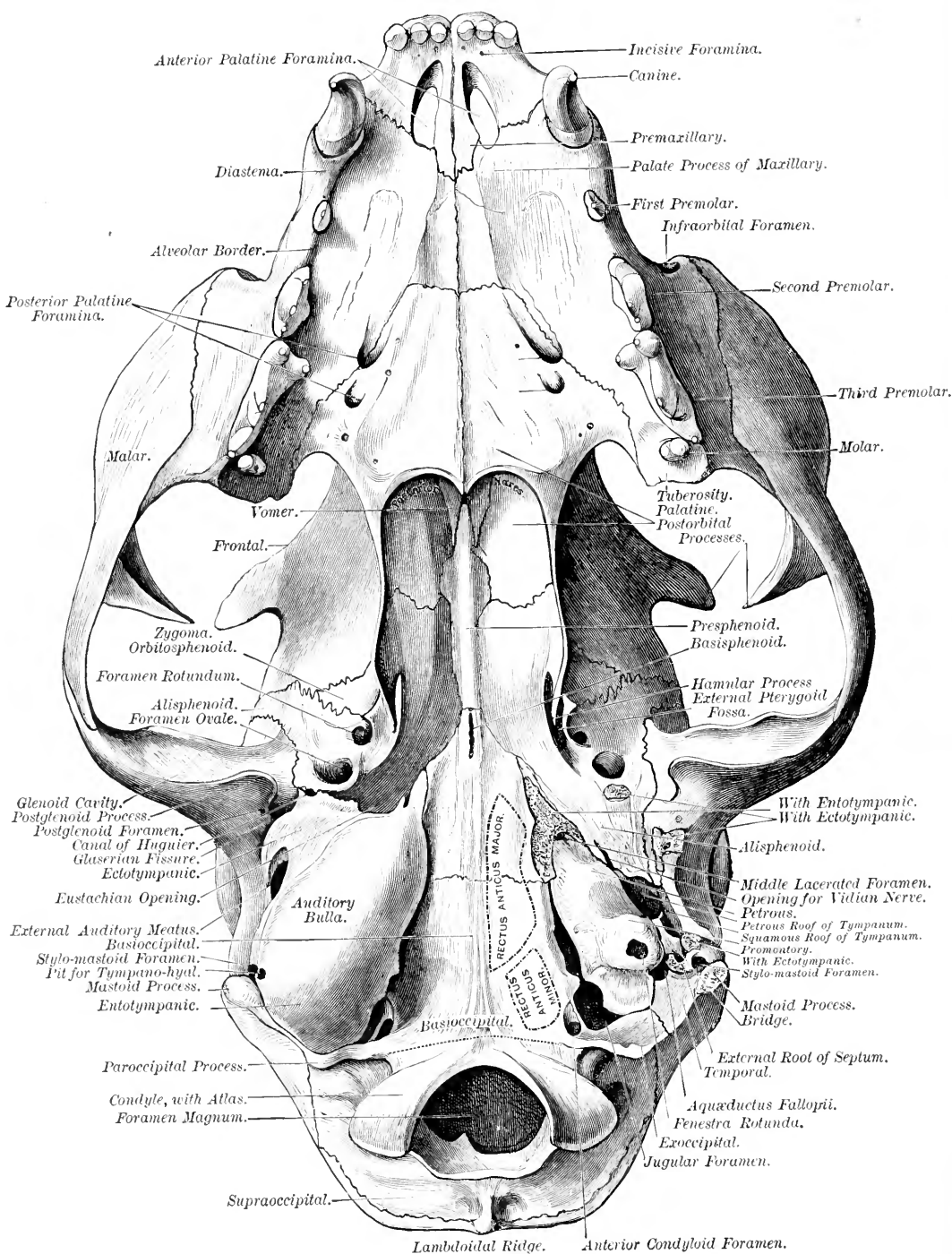
The student will find this classification of the bones of the cranium of great assistance in remembering their names and relative positions; beyond this, however, it has no value. The origin of the skull from modified vertebræ has been a favorite field of investigation from the time of Goethe and Oken, who first propounded a vertebral theory of the skull; the most recent studies, however, tend to prove that, with the possible exception of the occipital region, the skull has an entirely independent mode of development, the details of which I shall consider at length in their proper place.

### THE OCCIPITAL BONE.

**General Description.**—The Occipital is a single, bilaterally symmetrical bone forming the back of the skull and the posterior portion of the base. It consists of two distinct parts,—namely, the

FIG. 107.

Incisors.

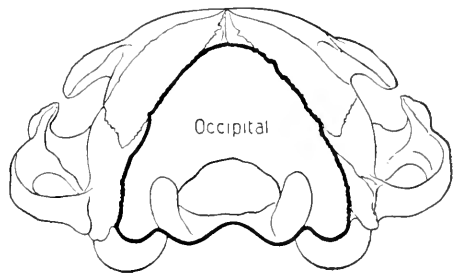


THE SKULL, LOWER ASPECT.



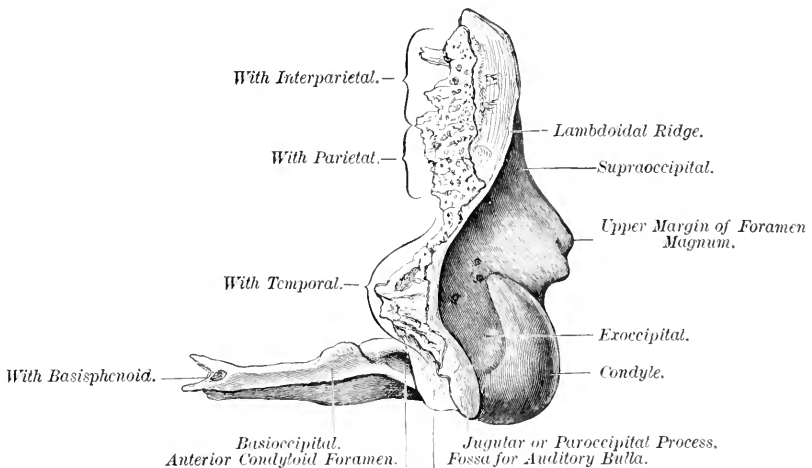
large occipital plate and the small basilar process. Of these the **occipital plate** (Fig. 108) is the broad, vertical, posterior part. It lies behind the interparietal, and extends transversely between the posterior ends of the parietals and the temporals, thus completing the back of the skull, except at the lower part, where a large occipital foramen (foramen magnum) permits the union of the brain with the spinal cord. At right angles to the occipital plate, the long, narrow, tongue-shaped, horizontal portion, the **basilar process** or **basioccipital** (Figs. 107, 109), projects forward to meet the posterior

FIG. 108.



POSITION OF OCCIPITAL BONE.

FIG. 109.



OCCIPITAL BONE, SIDE VIEW.

border of the basisphenoid. It lies between the temporal bones and supports the posterior part of the brain.

The upper part only of the occipital plate is free; the rest is covered by the heavy posterior cervical muscles. Very little, therefore, of the external surface of the occipital bone can be felt during life. The basilar process is deeply placed above and in front of the pharynx and the anterior cervical muscles attached to the head.

The **Occipital Plate** is divided into three areas, corresponding to the centres from which it is developed. The upper part is the supraoccipital; the lower parts on each side of the foramen magnum are the

exoccipitals; the basilar plate is often called the basioccipital. It presents for study two surfaces, three borders, and three angles:

The **posterior** or **external** surface is triangular, with the apex superior and the base inferior. It is separated into (1) a narrow anterior part and (2) a large posterior part by the **superior curved line** which assists in producing the **lambdoidal**<sup>1</sup> ridge of the skull.

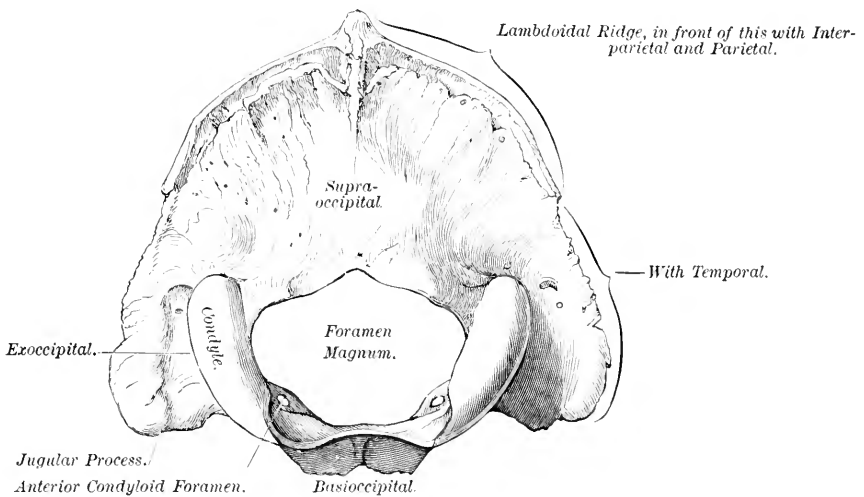
(1) The **anterior part** might be termed the expanded portion of the upper part of each lateral border (Fig. 109). It is not seen when the bone is viewed from behind, and it is the only surface of the bone which is visible when the skull is viewed from above. It is divided into right and left halves by the median enlargement of the superior curved line, known as the **external occipital protuberance**. This protuberance is triangular, the anterior angle being prolonged forward to join the longitudinal crest of the interparietal. The surface on each side of the protuberance is long and narrow, usually three times as long from above downward as it is wide from before backward. The posterior margin is formed by the curved line, and is elevated and regularly arcuate. The anterior margin is the upper part of the lateral border of the occipital plate, and is almost straight; it is bevelled to a varying degree, at the expense of the surface, for articulation with the interparietal and the parietal. It begins above at the front of the external occipital protuberance, and passes downward and slightly forward and ends below the middle of the distance measured from the protuberance above to the inferior angle below. Its termination forms a distinct angle with a short, irregular, transverse margin. The surface varies in length from before backward, according to the amount of bevelling of the anterior margin. It is convex from above downward and concave from before backward, the amount of concavity depending on the prominence of the lambdoidal crest. It is perforated by small, inconstant foramina leading to the diploë. The rough surface below the transverse lower margin is called the lower part of the lateral border of the occipital plate, and articulates with the temporal bone.

(2) The larger, **posterior part** of the external surface of the occipital plate (Fig. 110) is nearly vertical. It is bounded on each side, above, by the curved line; below, by the lateral border. The general direction of the lateral boundary is downward and outward.

<sup>1</sup> From *lambda*, the Greek letter *L*, and *eides*, like.

The upper half, formed by the curved line, is arcuate; the lower half is straight. The inferior angles are prominent, and, with the regions about them, are called the *jugular*<sup>1</sup> or *paroccipital*<sup>2</sup> processes. The lower margin is confined on each side to the lower margin of the process, and fades out in the middle on the lower surface of the basilar process, leaving between the line drawn as a continuation of their inner ends and the lower margin of the foramen magnum a narrow strip, a continuation below of the neck of the condyles. The *foramen magnum*, or *occipital foramen*, pierces the lower part of the occipital plate in the middle line. It is transversely

FIG. 110.



OCCIPITAL BONE, OUTER OR POSTERIOR SURFACE.

oval, about one-sixth wider than high. Its greatest width is contained twice in the greatest height of the plate, and its greatest height is contained about three times in the width of the plate at its base. It is subject to variations in size and details of shape. Its margin is sharply defined. On each side of the middle line above is a *tubercle*, more or less developed, for the attachment of the posterior occipito-atlantoid ligament. On the outside of this tubercle is an emargination marking the beginning of the condyle; then comes the sharp curved inner edge of the most elevated portion of the condyle; below this is a projection due to the tubercle of the check ligament lying within the wall; the lower part of the outline is regularly emarginate.

<sup>1</sup> From *jugulum*, the throat.

<sup>2</sup> From *para* (Gr.) beside, and occipital.

The surface around the foramen magnum is elevated. Above, it slopes away from the margin up to the curved line; at the sides, it forms the smooth, prominent condyles for articulation with the first vertebra; below, it is continuous with the external surface of the basilar plate.

Each **condyle** is an oval swelling, but the regular oval of its outline is encroached upon at its inner back part by the concave lower part of the margin of the foramen magnum. Its long axis is directed outward and upward in such manner that, while the lower end is on the margin of the foramen, the upper end lies to the outside of it. The condyle is slightly convex from side to side, and strongly convex from above downward. The highest part of the convexity is nearer the upper part than the lower, and is on a line which crosses the long axis obliquely, passing from about the middle of the inner margin to near the tip of the outer margin. The condyle is separated by a depression from the tubercle above, and at the side there is a well-marked constriction or neck.

Beyond the outer side of the condyle is a deep **excavation**, which begins above the condyle at the side of the central elevated sloping portion of the external surface of the bone and stops at the base of the paroccipital process. It is indistinctly divided by a transverse ridge at a level with the tip of the condyle into two parts, of which the upper is the smaller. These fossæ lodge the obliquus capitis superior muscle.

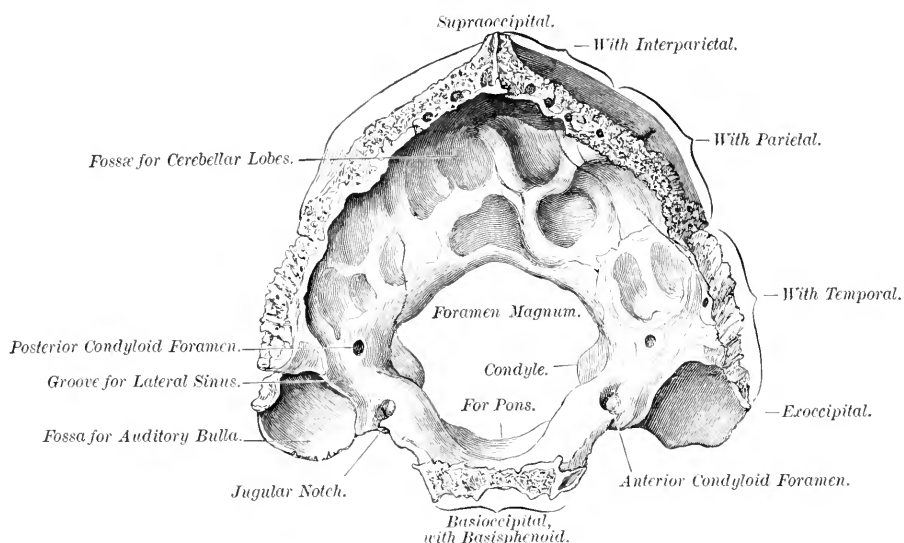
At the top of the external surface, below and almost in contact with the superior curved line, is a rough, narrow area, which joins the superior curved line on each side half-way down the lateral border. It affords attachment to several muscles.

From the middle point of the superior curved line a ridge, more or less marked, runs down toward the foramen magnum. This ridge is called the **occipital crest**, and varies much in development. In well-marked skulls, on each side of this crest, midway between the superior curved line and the foramen magnum is an obscure **inferior curved line**.

The **jugular processes** are the prominent inferior angles. Each process has a posterior or external surface and an anterior or internal surface. The **external surface** (Fig. 110) is gently convex in all directions, and its plane forms an angle with the plane of the general external surface and faces slightly upward as well as backward. The

inner third of its almost horizontal lower margin, where it springs from the side of the basilar process, is rounded and faintly emarginate. This emargination is known as the **jugular notch**, and forms the back margin of the **jugular foramen**. In its outer two-thirds the margin is more or less convex, prominent and tubercular, and is directed outward and slightly upward. It overlaps the auditory bulla and affords attachment to the stylohyoid and digastric muscles. On the posterior surface of the process is inserted the obliquus lateralis

FIG. 111.



OCCIPITAL BONE, INNER OR ANTERIOR SURFACE.

muscle. The anterior or **internal surface** (Fig. 111) of the jugular process is triangular, with the apex of the triangle above.

At the inner side of its lower margin, in the jugular notch, is the anterior opening of the **anterior condyloid canal**, above which a faint groove ascends upward and inward. Outside of these markings is a moderately wide, shallow, vertical groove, which passes from below upward and outward and is the lower end of the groove for the **lateral sinus** ending in the jugular foramen. Outside of this again, and occupying most of the surface, is a rough triangular **fossa**, which faces downward and forward, and into which is fitted the posterior end of the auditory bulla. Above this fossa is a smaller, less rough, triangular area, which joins the posterior end of the petrous part of the temporal bone. These triangular spaces are limited on the outside by the rough border for articulation with the mastoid part of the temporal bone.

The **internal** or **anterior surface** of the occipital plate (Fig. 111) is smaller than the external surface, inasmuch as the upper part of the external surface and the wide lateral borders are formed at its expense. It has the form of an arch thrown over the foramen magnum. It is narrower at the sides than above, and its lower margin is for most of its middle distance the curved anterior superior margin of the canal of the foramen magnum. At the sides it passes down into the anterior surface of the paroccipital processes. The upper and outer margin is the lateral border, articulating, as before mentioned, with the interparietal, the parietal, and the mastoid of the temporal.

The internal surface is concave from side to side and from above downward, and faces forward. It is deeply marked by pits for convolutions of the part of the brain called the cerebellum. Of these pits, a deeper median vertical pit, divided often into two by a transverse ridge, covers the vermiform appendix of the cerebellum, but is by no means constant or median and symmetrical. The groove for the lateral sinus crosses the surface obliquely, beginning above on the lateral margin at a point where the parietal and the temporal meet, and ending in the jugular notch below. Under its inner margin, half-way down, is the oval anterior opening of the **posterior condyloid canal**.

Inasmuch as the anterior and posterior margins of the foramen magnum are separated by a considerable interval,—namely, the thickness of the occipital plate of the bone,—there is formed between the two an occipital canal, whereof the plane is directed from below obliquely upward and backward. Its floor is slightly concave from side to side and convex from behind forward, and in front is not clearly defined from the floor of the basilar process. Each wall is narrower above and below than half-way up, where it is enlarged by the swelling produced on the posterior border by the prominent part of the occipital condyle. The roof of the canal is narrow and concave in both directions. On each side where the roof passes into the wall, midway between the two borders, is the posterior opening of the **posterior condyloid canal**, which pierces the bone obliquely and appears again, as has been said, in the groove for the lateral sinus. It transmits a vein. In front, behind a swelling at the point where the wall passes into the floor, is the posterior opening of the **anterior condyloid canal**, which opens anteriorly into the jugular notch. It trans-

mits the hypoglossal nerve. A rough pit and tubercle within the posterior border, just below the most prominent projection of the condyle, mark the attachment of the check or odontoid ligament of the axis.

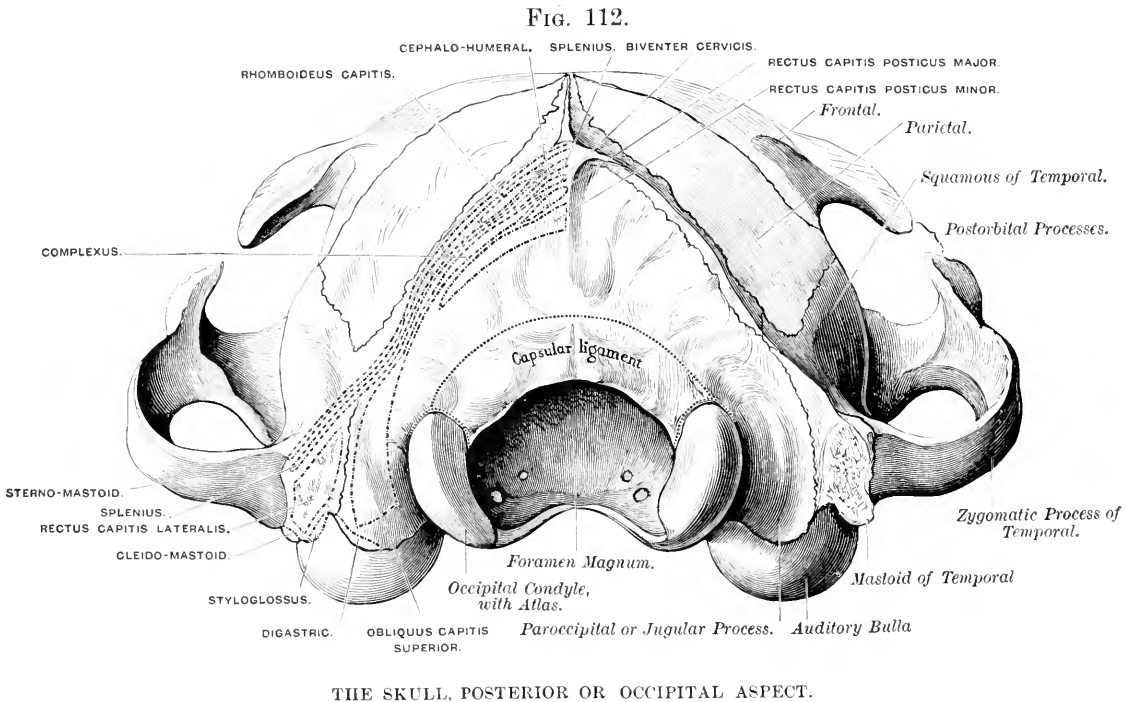
The **Basilar Process** of the occipital bone is a simple horizontal plate, projecting forward below and in front of the foramen magnum and at right angles to the rest of the bone. It is slightly longer than wide, and it has an upper and a lower surface and an anterior and two lateral borders.

The **upper surface** (Fig. 111) appears in the interior of the cranium as the floor of the posterior cranial fossa. It is narrower in front than behind, concave from side to side, especially at the back, and supports the part of the brain called the pons. It articulates in front by a straight suture with the basisphenoid. Each **lateral border** is directed from the anterior border backward and slightly outward as far as the posterior quarter, where it is emarginate and forms the inner boundary of the jugular foramen. The lateral border is sometimes grooved for the inferior petrosal sinus, which lies between it and the contiguous border of the petrous part of the temporal.

The **lower surface** (Fig. 107) is about as long as wide; it begins behind at a line connecting the inferior margins of the paroccipital processes and ends at the anterior border. In front of the jugular notch, each lateral margin is bevelled at the expense of the lower surface and is applied to the entotympanic portion of the auditory bulla. The inner edge of this bevelled border is more or less raised, and, near the jugular notch, is incised for the passage of nerves and vessels. On each side of the middle line the surface is crossed, anterior to the centre, by a transverse or slightly oblique rough line which marks the anterior limit of a **fossa**, whereof the deepest point is anterior and lateral. In this fossa is inserted the rectus capitis anticus minor muscle. The median space between the fossæ is elevated into a more or less prominent crest. On each side of a faintly depressed median longitudinal area, in front of the transverse rough lines, the lower surface is slightly convex transversely for the insertion of the rectus capitis anticus major muscle.

The **anterior border** of the basilar process is wide and low. In young skulls it is joined by cartilage to the posterior surface of the sphenoid bone; in full-grown and old skulls the cartilage is converted into bone and all traces of the original suture disappear.

**Nomenclature.**—*Occipitium* or *occiput*, the Latin for the back part of the head, is derived from *ob*, against, and *caput*, the head. Hence we have occipital bone, or *os occipitale*, or *os occipitis*. The Germans use *das Hinterhauptbein*; the French, *l'occipital*. The bone has had many synonyms, and some are found in the less recent human anatomies,—for example, *os puppis*, the bone of the stern, because the top of the skull, when sawed off (the calvarium) and turned over with the hollow side up, was thought to resemble a boat,



whereof the back part was represented by the occipital bone; and *os memoriæ*, because of its relation to the part of the brain once thought to be the seat of memory.

**Ossification.**—The occipital bone is developed from four parts. The part above the foramen magnum is known as the supraoccipital, the parts which bear the condyles are the exoccipitals, and the part below the foramen, corresponding to the basilar process, is the basioccipital.

**Articulation.**—The occipital articulates with the interparietal, the parietals, the temporals, and the sphenoid.

**Muscular Attachments.**—The muscles attached to the occipital are: the rectus capitis anticus major and minor and the muscular pharynx to the lower surface of the basilar plate (Fig. 107); the di-



gastric (Fig. 112) to the lower edge of the jugular process, the obliquus capitis lateralis to its external surface, and the following to the external surface of the occipital plate in the order named from above downward: the cephalo-humeral, the rhomboideus capitis, the splenius, the bi-venter cervicis, the complexus, and the rectus capitis posticus major and minor.

## VARIATIONS IN THE OCCIPITAL BONE.

## VARIATIONS IN SIZE.

OCCIPITAL PLATE.			FORAMEN MAGNUM.		CONDYLES.	BASILAR PROCESS.	
Height.	Width.	Height above Foramen.	Height.	Width.	Spread.	Length.	Width.
28	31	15	13	13	22	17.5	14
26.5	33	15	12.5	13.5	23	17	15.5
26	31	16	11	13	21	16	14
26	36	17	11	13	21.5	17	15
26	31	17	11	12	21	17	14
25.5	30	16	11.5	13	22	15	14
25.5	32	15	11.5	13.5	22	15	14.5
25	33	16.5	10	14	22.5	17	15
25	31	16	11	13.5	21	15	14
25	31.5	16	11	13.5	22	15	14
25	31	16	11	13	21	16	14
25	32	16	11	14	23	16	14
25	30	14	11	14	22	15.5	14
25	30	17	9.5	12.5	20.5	16.5	14
25	31	15	11	12	20	16	14
24.5	30.5	14.5	11.5	13	21.5	15	13
24	30	13	11.5	13	21	14	13
24	28	14	11	12.5	20	15	13.5
24	29.5	13	12.5	13.5	21	15	13
24	32	15	10	14	22	14	14
24	31	15	10	12	19	17	13
24	28	14	12	12	18.5	13.5	12
24	33	14.5	10	12.5	20	15	14
24	32	14.5	12	14	22	15	14
24	32	15	11	13.5	21.5	15	14
23.5	31	15	10	12.5	22	14	14
23	30	14	11	13	20.5	14.5	14
23	28.5	15	10.5	12	19	14	13
23	29	14	10	12.5	21	15	14
23	31	15	11	15	22.5	14.5	13
23	32.5	16	9	13	21	16	14
23	29.5	14.5	10	13	21	13.5	14
23	30	14.5	10.5	12.5	21	13.5	13.5
23	30	14	10	12	21	15	14.5
23	31	14	10	13.5	21	14.5	14
22.5	29.5	14	10	13.5	21.5	13	14
22.5	28.5	13.5	11	12	19	13	13
22	28	14.5	10	12.5	20	13	14
22	28	13	10.5	12	20	15	13.5
22	28	14.5	10	13	22	15	13
22	29	13.5	10	12	20	14.5	13

The measurements were taken as follows :

The height of the occipital plate is the distance from the highest point on the superior curved line, at the external occipital protuberance, the so-called **inion**,<sup>1</sup> to the lowest middle point of the thin lower margin of the foramen magnum, the so-called **basion**.<sup>2</sup>

The width of the occipital plate is its greatest breadth across the jugular processes.

The height of the part of the external surface above the foramen magnum is the distance from the inion to the middle point of the upper margin of the foramen, a point known as the **opisthion**.<sup>3</sup>

The height of the foramen magnum is its vertical diameter. The height of the occipital plate is usually less than the height of the part above the foramen added to the height of the foramen itself, because it is measured on the shortest line between the inion and the basion.

The width of the foramen magnum is taken between the points where the condyles diverge from the lateral margins ; it represents, therefore, the greatest width and lies above the centre. The spread of the condyles is the greatest distance between their outer edges.

The length of the basilar process is the distance on its lower surface from the edge of the foramen magnum ; that is, from the basion to the middle of the anterior border, a point difficult to locate accurately in skulls wherein the occipital and the sphenoid have completely coalesced.

The width of the basilar process is the distance between the inner, concave margins of the jugular notches, just in front of the anterior openings of the anterior condyloid canals.

The relation between two measurements of any part of the skeleton is usually expressed by means of a so-called index. This is derived from a proportion which shows the relation between the measurements when one measurement is put at one hundred. For example, the proportion for the index of height of the occipital plate is :

$$\begin{aligned} \text{Width : height} &:: 100 : x. \quad \text{Index of height} = \frac{\text{height} \times 100}{\text{width}}, \\ \text{or } \frac{28 \times 100}{31} &= 90.32 ; \text{ or } \frac{26 \times 100}{36} = 72.2. \end{aligned}$$

<sup>1</sup> (Gr.) the back of the head.

<sup>2</sup> From *basis* (Gr.), the base.

<sup>3</sup> From *opisthios* (Gr.), hinder.

By this means occipital plates may be classified into broad and narrow plates, according as the index is above or below a given number.

#### VARIATIONS IN DEVELOPMENT.

The **occipital plate** may be triangular or almost quadrate, and both forms present narrow and broad types.

On the **external surface** the occipital protuberance and the lambdoidal crest may be very greatly developed, and the occipital crest may extend downward almost to the foramen magnum.

The angle which the plane of the occipital plate forms with the plane of the foramen magnum is a variable one; it is greater when the tubercles above the foramen are unusually large.

The shape of the **foramen magnum** varies from round to transversely oval; it is not always regular or symmetrical.

The **internal surface** of the occipital plate exhibits variations in the size and form of the fossa for the vermiform lobe of the cerebellum. Of forty occipitals examined with reference to this variation, two had the fossa median and symmetrical; in six it was obscure and irregular; in thirty it was bowed to the right; and in two only was it bowed to the left. The fossa may be separated by a transverse ridge from the margin of the foramen magnum, or the two features may be continuous.

The **anterior condyloid canal** appears to be always present; it may, however, be double, completely or partially, on one side or on both sides. In one specimen studied, the anterior opening on the left side was high up in the groove for the lateral sinus.

The **posterior condyloid canal** is sometimes absent, on one or on both sides; it is often double, presenting two anterior and two posterior openings; or it may be only partially divided, presenting two posterior and one anterior or one posterior and two anterior openings. When there are two posterior openings they are generally close together, but the two anterior openings may be widely separated. If the anterior opening be apparently absent from its usual position in the groove for the lateral sinus, or if it be very small, or single, when the canal appears to be double, an accessory opening will be almost always found in the lateral wall of the anterior opening of the anterior condyloid canal.

An abnormal foramen is sometimes present in the root of the

jugular process, in the interval between the condyle and the root of the basilar process.

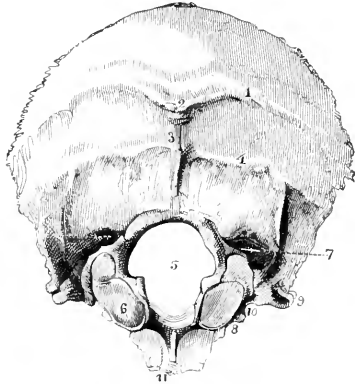
The inner part of the lower edge of the jugular process, near the condyloid foramen, is often incised; more rarely at this point is a small antero-posterior canal.

### HUMAN OCCIPITAL BONE.

In the human occipital bone the basilar process is relatively smaller, and the occipital plate, which is oval in outline, is bowed strongly forward.

On the external surface (Fig. 113), near the middle, is the **external occipital protuberance**, from which the **superior curved line**

FIG. 113.



OCCIPITAL BONE. EXTERNAL VIEW.

1, superior curved line; 2, external occipital protuberance; 3, external occipital crest; 4, inferior curved line; 5, occipital foramen; 6, condyle; 7, fossa behind the condyle, into which the posterior condyloid foramen frequently opens; 8, position of anterior condyloid foramen; 9, jugular process; 10, notch contributing to form the jugular foramen; 11, basilar process.

arches outward on each side to the **lateral angle**. The area above the line is smooth and faces upward and backward; it is developed in membrane as a distinct bony element, and corresponds, in part at least, to the interparietal of the cat. Traces of the original occipito-interparietal suture are sometimes found in adult bones, most frequently as incisions in the borders. The area is marked by two obscure **highest lines** passing forward and outward from the protuberance to the anterior border. The area below the protuberance is a continuation backward and upward of the base of the skull. It exhibits the median **external occipital crest**, from the middle point of which

the **inferior curved lines** arch downward, outward, and forward toward the jugular processes.

The lateral border, between the lateral angle and the jugular process, is sometimes incised at the point which marks the end of the original suture between the supraoccipital and the exoccipital.

Each **jugular process** is small, and its intracranial surface is marked by the lower part of the lateral sinus. Inasmuch as there is no auditory bulla on the human temporal bone, the temporal articular surfaces of the jugular process are less extensive.

The **occipital condyles** are flatter than those of the cat, and, owing to the position in which the head is held upon the vertebral column, their articular surfaces are more nearly parallel to the plane of the base of the skull.

The **occipital foramen** (foramen magnum) is oval, with the major axis in the long axis of the skull. When the **posterior condyloid foramen** is present its posterior opening lies in a fossa above the condyle, and its anterior opening appears near the jugular notch in the groove for the lateral sinus.

The **internal surface** (Fig. 114) of the occipital plate is divided into an upper and a lower part by a transverse groove, bordered by prominent ridges and elevated at the median point into an **internal occipital protuberance**. The part above the groove appears to correspond to the posterior part of the intracranial surface of the parietals in the cat.

The groove lodges the lateral sinus, and the ridges afford attachment to the membranous tentorium cerebelli. In the cat the tentorium is a bony plate; hence its base, or attached edge, is tunnelled by the sinus. From the internal protuberance a **vertical groove** passes upward to the superior angle and lodges the superior longitudinal sinus in the falx cerebri. At the point where the vertical groove meets the transverse groove, in the middle line, or more frequently to the right of it, there is occasionally a **circular fossa**, which receives a dilata-

tion of the sinuses, known as the torcular<sup>1</sup> Heroph'ili.<sup>2</sup> A vertical ridge, the **internal occipital crest**, passes downward from the protuberance and affords attachment to the falx cerebelli. Its lower part may be excavated to receive the vermiform process of the cerebellum. Through this cross-shaped arrangement of grooves and crests the internal surface is divided into four concave areas, whereof the

FIG. 114.



OCCIPITAL BONE. INTERNAL VIEW.

1, fossa for the cerebrum; 2, fossa for the cerebellum; 3, groove for the longitudinal sinus; 4, internal occipital crest for the attachment of the cerebellar falx; 5, groove for the lateral sinus; 6, internal occipital protuberance; 7, occipital foramen; 8, basilar process; 9, 10, groove for the lateral sinus, descending on the jugular process to the jugular notch; 11, border for the parietal bone; 12, border for the temporal bone; 13, position at which the ninth, tenth, and eleventh cerebral nerves pass through the jugular foramen; 14, anterior condyloid foramen.

<sup>1</sup> A wine-press.<sup>2</sup> Herophilus (about 300 B.C.).

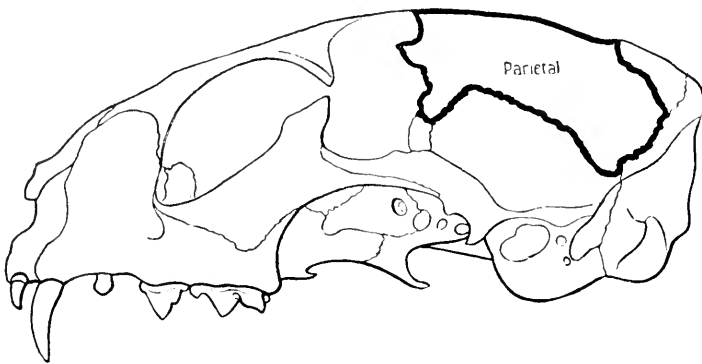
two upper cover the cerebrum and the two lower support the cerebellum.

The **basilar process** is very little wider than it is thick. On its lower surface is a median projection, the **pharyngeal tubercle**, for the attachment of the median part of the pharynx. Its lateral surface is roughened for articulation with the petrous of the temporal. The quadrate anterior surface joins the sphenoid. The jugular notches are prolongations of the grooves for the lateral sinuses, and the anterior condyloid foramina pierce arching plates, sometimes called the **jugular tubercles**, which are impressed transversely by grooves for cranial nerves.

### THE PARIETAL BONES.

**General Description.**—The Pari'etals are two thin, curved plates which are united by their upper edges to form the back part of the vault of the cranium (Fig. 115). They are joined in front to the

FIG. 115.



POSITION OF LEFT PARIETAL BONE. SIDE VIEW.

frontals, below to the sphenoid and the temporals, and behind to the occipital and the interparietal.

Each parietal is nearly square, a little longer than high, and presents on examination two surfaces, four borders, four angles, and an internal plate-like tento'rium<sup>1</sup> or tentorial process.

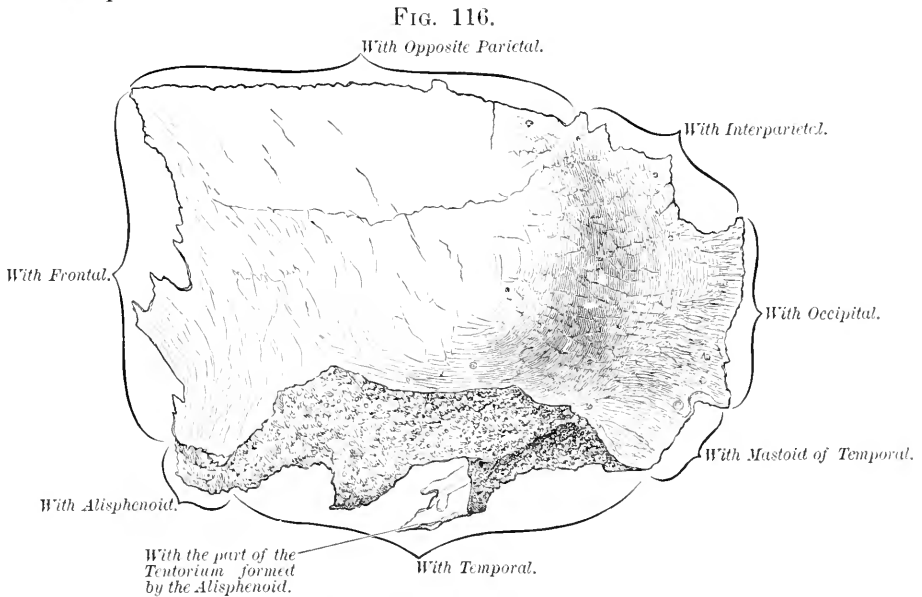
The **outer surface** (Fig. 116) is strongly convex, except for a narrow strip along the posterior border which is flat or even slightly concave from before backward. The highest point of the convexity is somewhat behind and above the centre of the bone, and is known as the **parietal eminence**. Below this eminence a faint curved **temporal**

<sup>1</sup> A tent.

ridge runs parallel to the lower border, and indicates the attachment of the temporal fascia. The lower part of the surface is marked by a crescentic rough area for articulation with the overlapping squamous plate of the temporal.

The **inferior border** is short, emarginate, and irregular, often presenting near the middle a large tooth-like process. Near its posterior end it is joined obliquely by the outer border of the tentorium.

The **anterior-inferior angle** is produced downward, and is more or less truncated. It is overlapped by the upper part of the inner surface of the alisphenoid.



LEFT PARIETAL, OUTER SURFACE.

The **anterior border** is in the main straight and at right angles to the superior and inferior borders. It is serrated, and overlaps the posterior border of the frontal, in a larger degree at a point a little below its middle, where a sharp process nearly reaches the base of the frontal postorbital process. The suture resulting from the fronto-parietal union is known as the **coronal**. Near the upper angle in the thicker part of the border is often a foramen, the opening of a large diploic canal which is continued forward into the frontal bone.

The **anterior-superior angle** is well marked and is almost a right angle. Its point of union with the angle of the other parietal and with the contiguous angles of the frontals marks the region on the skull known as the **bregma**.

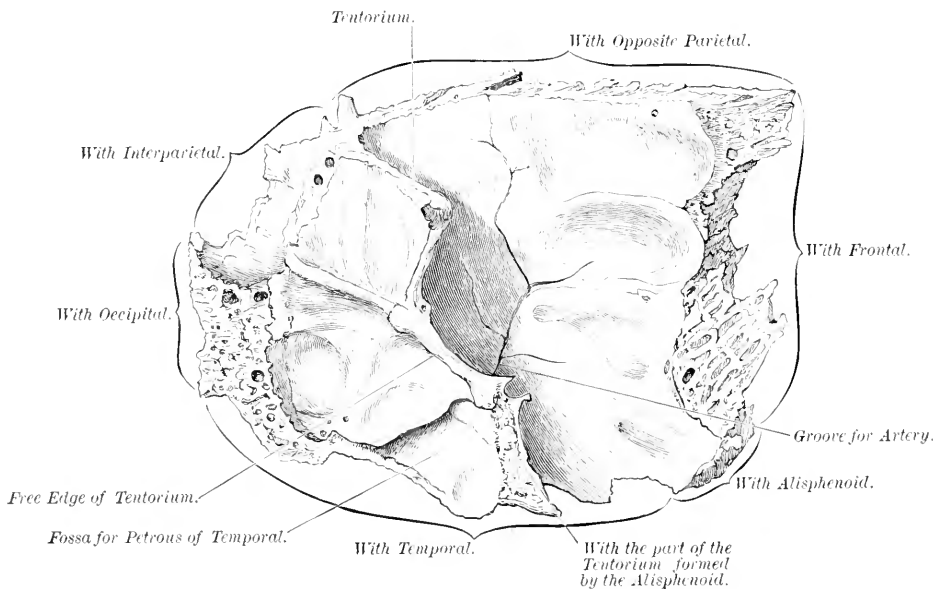
The **superior border** is the longest; it is straight, slightly serrated, and is united to the corresponding border of the opposite parietal by the **sagittal suture**.

The **posterior-superior angle** is cut off obliquely and becomes that curved upper part of the posterior border which articulates with the interparietal.

The **posterior border** is arcuate; it is bevelled at the expense of the inner surface, especially above, and overlaps the interparietal and occipital bones. Near its upper end is a large foramen for a venous sinus. Its lower end terminates in the **posterior-inferior angle**, which is more or less prominent.

The **inner surface** (Fig. 117) is deeply concave, and is marked by

FIG. 117.



LEFT PARIETAL, INNER SURFACE.

three longitudinal and three vertical wide grooves, which fit over the convolutions of the middle lobe of the brain. The upper longitudinal groove runs the length of the bone and ends posteriorly in the upper part of the interval between the base of the tentorium and the back part of this surface. The middle longitudinal groove does not run so far back, but ends by turning downward to join the posterior and larger vertical groove. The lower groove is joined in front and behind by the upper ends of the anterior and middle vertical grooves, which are continued down on the inner surface of the squamous of the



temporal. At a variable point on the lower margin is the beginning of a vertical **arborescent groove** for the meningeal artery. The groove is a continuation of the groove on the anterior surface of the tentorium.

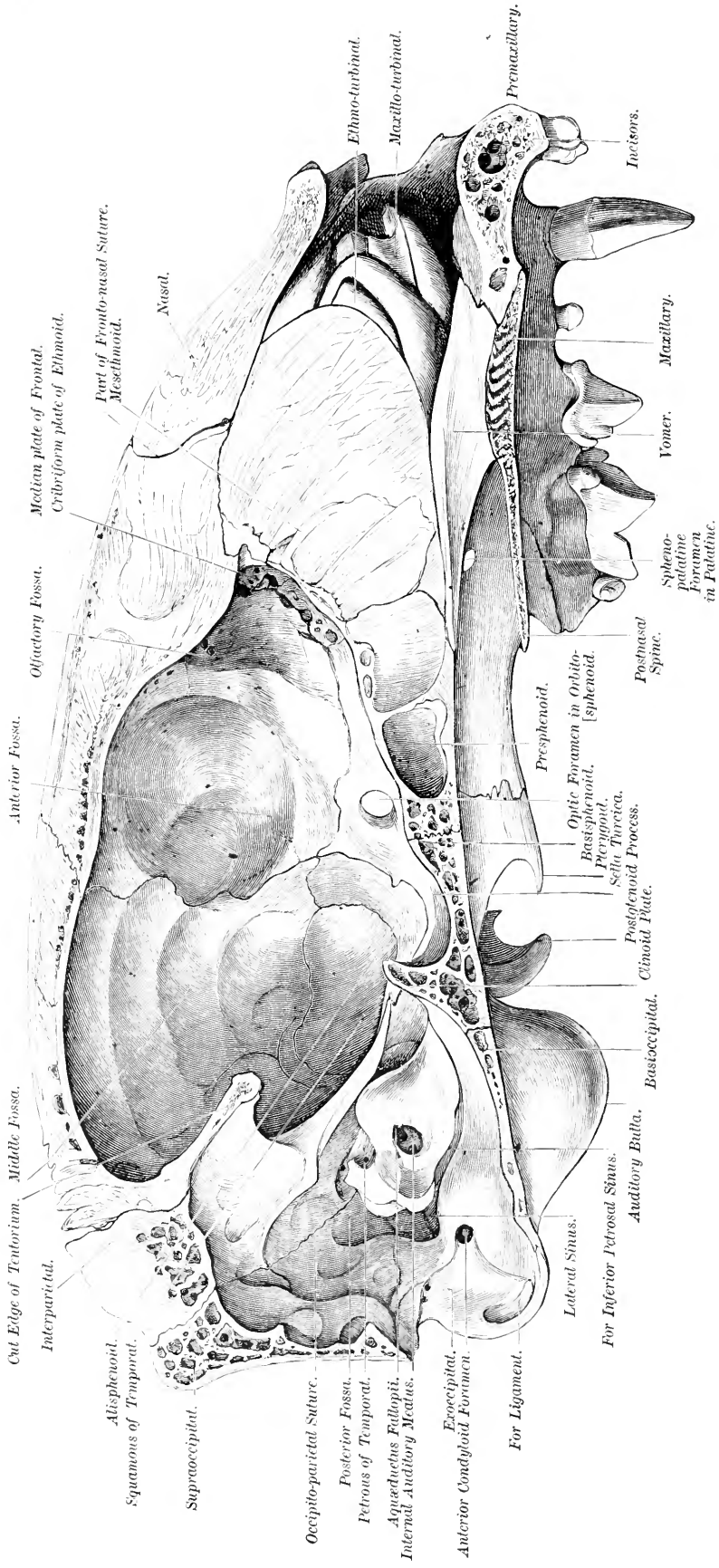
The **Tentorium** or **tentorial process** is a plate of bone directed downward and forward and also inward at an angle of forty-five degrees from the posterior border of the inner surface. It is about one-third as large as the bone itself.

Its **inner border** is straight and joins the process on the other parietal; its **outer border** is in part the posterior half of the inferior border of the bone, in part independent and short, joining the inner surface of the squamous part of the temporal. The **anterior** or **lower border** consists of a lower and an upper part. The lower part, composing about one-third of the border, is transverse, slightly emarginate, and exhibits a prominent inner angle. It is jagged and bevelled at the expense of the posterior surface, and it articulates with the alisphenoid by overlapping its tentorial process. In its upper two-thirds the border is deeply emarginate and the upper angle is apparently produced downward. This part of the border is rounded, or slightly swollen, and affords attachment to a membrane of the brain called the dura mater.

The **upper surface** of the tentorium is almost flat, and is marked by some irregular depressions for cerebral convolutions and by occasional openings and grooves for cerebral vessels. Of these grooves, the one beginning at the inner lower angle and running obliquely upward and outward is very constant. The upper surface faces forward, outward, and upward, and supports the lower surface of the middle lobe of the brain. It turns forward above into the internal surface of the bone.

The **lower surface** of the tentorium faces downward, backward, and inward. It shows three distinct portions: (1) an upper, median portion, which is quadrate, slightly concave, faces inward more than the other portions of the surface, and covers part of the cerebellum (Fig. 118). (2) External to this portion, and separated from it by a longitudinal ridge, is the second portion, which forms a large triangular area, also concave, covering the lateral part of the cerebellum. It is marked by faint secondary fossæ, and exhibits on its posterior border a groove and a foramen for the lateral sinus. (3) Below and in front

Fig. 118.



THE SKULL, SIDE VIEW OF CRANIAL AND NASAL CAVITIES.

of this portion, and separated by a sharp overhanging oblique line, is a roughened triangular fossa, which is applied to the superior surface of the petrous part of the temporal bone.

**Nomenclature.**—The word parietal is derived from the Latin *paries*, a wall. *Os parietale*, *das Scheitelbein*, and *le pariétal* are the names in Latin, German, and French respectively.

**Determination.**—When the concave surface is held toward the student and the straight median border upward, the tentorial plate will be on the side to which the bone belongs.

**Articulation.**—The parietal articulates with the frontal, the interparietal, the sphenoid, the temporal, and the occipital, and with its fellow of the opposite side.

**Muscular Attachment.**—The temporal muscle is attached to the outer surface of the parietal.

**Ossification.**—The parietal appears to develop from two centres of ossification near the parietal eminence.

#### VARIATIONS IN THE PARIETAL BONE.

##### VARIATIONS IN SIZE.

The following list exhibits the variations in the size of fifty parietals. The first number represents the length; the second, the height; R or L shows the side of the skull to which the bone belongs.

The length is the maximum length from the anterior superior angle to the point where the superior border intersects an imaginary straight line drawn at right angles to it through the most convex point of the posterior border.

The height is the greatest vertical diameter measured from the inferior border at right angles to the long diameter:

42, 30, R; 42, 27, L; 41, 27, R; 40.5, 26, L; 40, 30, R; 40, 27, R, L; 40, 24, R; 39.5, 27, R; 39, 27.5, R; 39, 27, R, L; 39, 26, R; 39, 25, L; 38.5, 28, R; 38.5, 27, R; 38.5, 24, L; 38.5, 22, R; 38, 30, R; 38, 28, L; 38, 27, L; 38, 26, R, L; 38, 25, L; 37, 28, R; 37, 27.5, R; 37, 27, L; 37, 26, R, L; 37, 25.5, R; 37, 25, R; 36.5, 27, L; 36.5, 25.5, L; 36.5, 24.5, L; 36, 27, R, L; 36, 26, L; 36, 25.5, R, L; 35.5, 25, L; 35, 28, L; 35, 27, L; 35, 26, L; 35, 25.5, L; 35, 25, R; 35, 24, R; 35, 23, L; 34.5, 26, L; 34, 28, R, L; 34, 26, L; 34, 25, L; 33.5, 25, L; 33.5, 24, L; 33, 27, L; 33, 23, R; 30, 23, L.

## VARIATIONS IN DEVELOPMENT.

The **external surface** of the parietal may be almost flat or it may be strongly convex; the maximum convexity, or parietal eminence, varying also in position.

In some specimens the articular surface for the squamous of the temporal is reduced to a narrow strip along the inferior border; in others it may occupy the lower fourth of the surface, rising still higher at the anterior end.

A curved ridge passing from the superior border at the anterior end of its articulation with the interparietal to the upper third of the anterior border often marks an attachment of the temporal muscle and cuts off a superior triangle which is smooth and more dense than the rest of the surface.

One specimen in my collection exhibits behind the middle of the bone a deep vertical groove which divides the external surface into two parts. Whether this is the marking of a blood-vessel, the result of an injury, or a defect in development is not possible to determine, but it is interesting because a similar variation has been observed in the human parietal.

In some specimens a foramen may be seen near the middle of the posterior border, and in one immature parietal there is a small opening just above the articular surface for the squamous.

The only variations observed on the **internal surface** are variations in the groove and the foramina which are situated near the posterior border and lodge or transmit the lateral and superior petrosal sinuses. In some specimens there is a distinct groove for the lateral sinus leading to a foramen above the middle of the border; in others the groove is present but the sinus enters the interparietal or the occipital, and in others again there is neither groove nor foramen. The superior petrosal sinus very often enters a foramen near the lower part of the groove for the lateral sinus.

## THE INTERPARIETAL BONE.

**General Description.**—The Interparietal is the smallest of all the cranial bones. It is single and unpaired, and situated at the back part of the roof of the cranium, in the median line between the diverging upper posterior corners of the two parietals and in front of the upper end of the vertical plate of the occipital (Fig. 119).

In outline it is triangular; one angle points directly forward, and the opposite side is posterior and transverse.

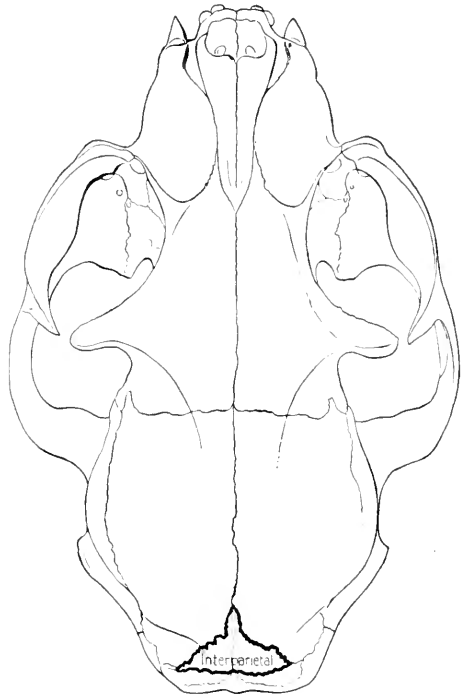
The interparietal presents an outer or upper surface and an inner or lower surface, and these are separated behind by the narrow posterior surface, and in front and at the sides by the lateral borders, which together form a strongly convex anterior surface.

The outer surface (Fig. 120) is triangular. The posterior margin is emarginate, and each lateral margin is serrated and directed from without inward and forward and separated behind from the posterior part of the lateral outline of the bone by part of the bevelled lateral surface. The outer surface is divided into right and left halves by a median longitudinal ridge, which forms part of the sagittal crest of the skull and is produced on this bone in front into a spine, more or less distinct. On each side of the crest the surface is slightly concave and slopes downward, outward, and forward, and is smooth and covered by the temporal muscle.

The inner surface is triangular, or may be transversely oblong if the anterior angle be cut off transversely. Its posterior margin is encroached upon by the bevelled posterior surface. Its lateral margins are jagged, and either end in front in an angle or round into an arcuate anterior margin. The surface is strongly concave from side to side, smooth, and marked by small depressions. It is continuous in front with the median part of the posterior surfaces of the tentorium of the parietals, and continuous behind with the upper part of the internal surface of the vertical plate of the occipital, and contributes to form the fossa for the cerebellum.

The posterior border or surface is concave from side to side,

FIG. 119.

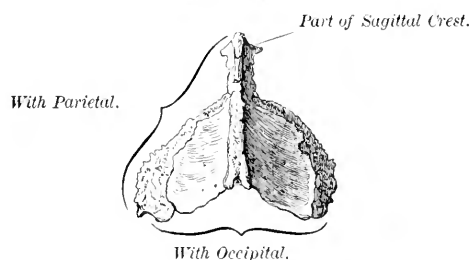


POSITION OF INTERPARIETAL BONE.

and is bevelled from above downward and forward. It is rough for articulation with the anterior border of the upper part of the occipital, and exhibits openings into the diploë, which are the ends of vascular channels.

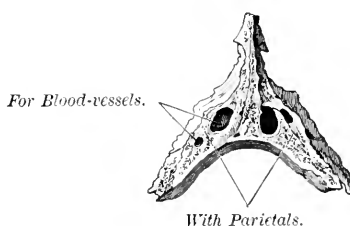
The **anterior surface** (Fig. 121) presents a median portion, with the outline of an erect triangle facing forward, and lateral parts, bevelled at the expense of the upper surface, facing upward, outward, and forward. The median portion has an angular or emarginate lower margin and a prominent produced upper angle. It is concave from above downward, and is frequently pierced on either side of the middle

FIG. 120.



INTERPARIETAL, OUTER SURFACE.

FIG. 121.



INTERPARIETAL, ANTERIOR SURFACE.

by large vascular foramina, whereof one is large and usually best developed on the right side and appears to represent the continuation into the skull of the longitudinal sinus in the dura of the brain. The anterior surface is closely applied to the posterior borders of the parietals.

In skulls of advanced age the interparietal may be found firmly united with the neighboring bones.

**Nomenclature.**—The term interparietal is from *inter*, between, and parietal. The German term is *das Zwischenscheitelbein*; the French, *l'interpariétal*.

**Ossification.**—The interparietal is developed from two centres of ossification which early unite.

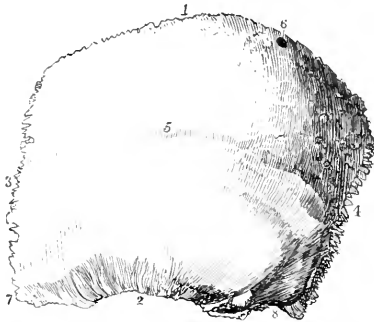
**Articulation.**—The interparietal articulates with the occipital and the parietals.

#### HUMAN PARIETAL BONES.

Most of the features of the parietal of the cat can be easily recognized on the human parietal. The tentorial process, however, is absent, and the entire bone is more strongly curved.

On the outer surface (Fig. 122) are two temporal ridges (the upper one often only faintly marked), and the parietal foramen near the posterior end of the superior border is larger and more constantly present.

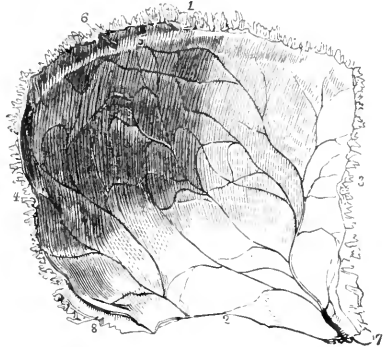
FIG. 122.



LEFT PARIETAL BONE. OUTER VIEW.

1, superior border; 2, bevelled inferior border, which articulates with the squama of the temporal bone; 3, anterior border, joining the frontal bone; 4, posterior or occipital border; 5, temporal ridge; 6, venous foramen; 7, prolonged anterior-inferior angle joining the summit of the great wing of the sphenoid bone; 8, posterior-inferior angle articulating with the mastoid portion of the temporal bone.

FIG. 123.



LEFT PARIETAL BONE. INNER VIEW.

1-4, borders corresponding with same numbers in former figure; 5, groove for the longitudinal sinus, and, communicating with it, a venous foramen; 6; 7, anterior-inferior angle; 8, posterior-inferior angle with the groove for the lateral sinus. The arborescent lines on the inner concave surface of the bone indicate grooves for the great meningeal vessels.

On the inner surface (Fig. 123) along the superior border is a distinct groove for the longitudinal sinus, and at the posterior-inferior angle is a part of the groove for the lateral sinus. The inner surface, although deeply concave, is not so deeply marked by the cerebral convolutions; it usually exhibits, however, near the superior border, irregular impressions made by the granular nodules of the dura called **Pacchionian**<sup>1</sup> bodies. The arborescent channels for the meningeal vessels are derived from two principal branches, one from the anterior-inferior angle and one from the middle of the inferior border.

All the borders are more strongly dentate than the borders on the parietal of the cat; the anterior, moreover, is straighter, lacks the upwardly directed projection, and is bevelled in its upper part at the expense of the outer surface.

### THE TEMPORAL BONES.

**General Description.**—The Temporals are paired bones situated on the sides of the skull just behind the orbits (Fig. 124). They

<sup>1</sup> Pacchioni (A.D. 1665-1726).

do not articulate together, therein resembling only the lachrymals, the malars, and the maxillo-turbinals, but are separated above by the parietals and below by the sphenoid and the occipital.

Each temporal bone lies in front of the occipital and the parietal, and behind the sphenoid, the parietal, and the malar. The external surface forms the lower posterior part of the side of the skull and enters into the formation of the temporal fossa. It gives off, midway in front, a stout, curved, zygomatic process, which has on its under

FIG. 124.



SIDE VIEW.

LOWER VIEW.

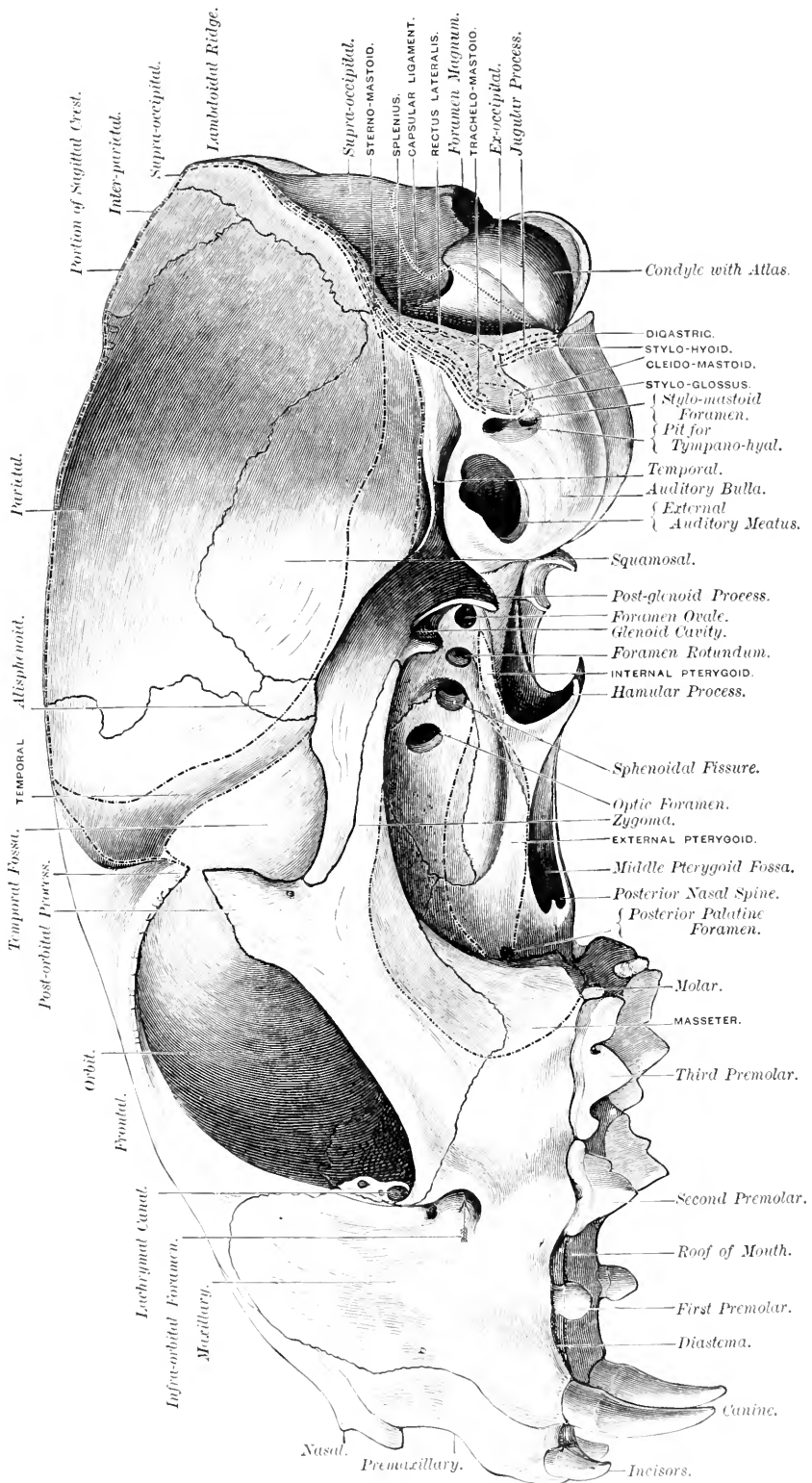
POSITION OF TEMPORAL BONE.

In the right hand figure the auditory bulla of the left temporal is removed.

surface the glenoid cavity for the articulation of the lower jaw with the skull, and is prolonged forward to join the zygomatic process of the malar to form the zygomatic arch. The external ear is attached behind the zygomatic process around the large opening,—the external auditory meatus. Behind the meatus is fastened the upper end of the chain of hyoid bones which support the tongue. The temporal appears on the base of the skull in the form of a large, ovoid, auditory bulla. In the cranial cavity the temporal is part of the floor and side-walls of the middle and posterior cranial



FIG. 125.



THE SKULL: THE LEFT SIDE.

fossæ. It contains three cavities, whereof two are in the auditory bulla and one is in the substance of the bone itself and contains the complicated organ of hearing, and hence is known as the cavity of the internal ear. One of the cavities in the bulla is the tympanum, or cavity of the middle ear.

The temporal consists of four parts, which correspond, in a measure, with the parts from which it is developed.

First, above is the thin, shell-shaped, **squamous** portion or squamosal, with its zygomatic process (Fig. 126); second, behind is the

FIG. 126.



OUTER VIEW.

INNER VIEW.

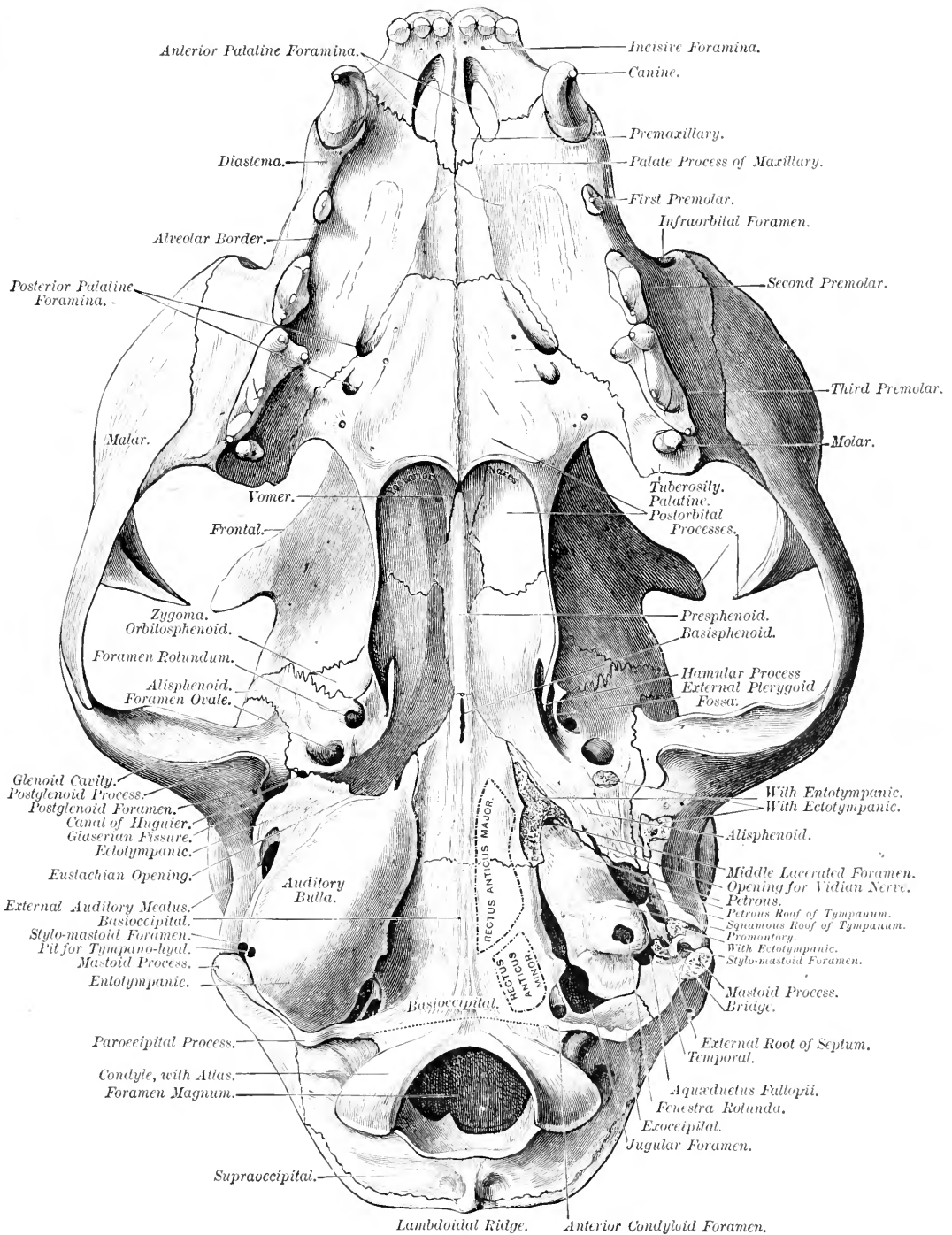
PARTS OF THE TEMPORAL BONE.

swollen **mastoid**; third, on the inside is a white, hard, pyramidal mass,—the **petrous** portion or petrosal. The under surface of the petrous would be visible on the base of the skull were it not for the fourth part, the **tympanic**, forming the auditory bulla. The bulla consists of two parts, separated by a groove parallel with its long axis and very near the lower margin of the auditory meatus. The outer part is denser, much smaller than the inner, and is developed from a separate ring of bone,—the tympanic bone. The bulla can be removed from the rest of the temporal, at its points of attachment behind, and in front of the auditory meatus; there are then exposed not only the inferior surface of the petrous, but also parts of the squamous and mastoid, which, with the petrous and part of the sphenoid bone, form the roof of the tympanum, whereof the floor is contributed by the bulla itself (Fig. 127). For convenience the bulla may be removed and described after the consideration of the three other parts. The tympanum will be studied separately.

The squamous and petrous portions coalesce behind with the mastoid, but for the rest of their circumference are free.

FIG. 127.

Incisors.

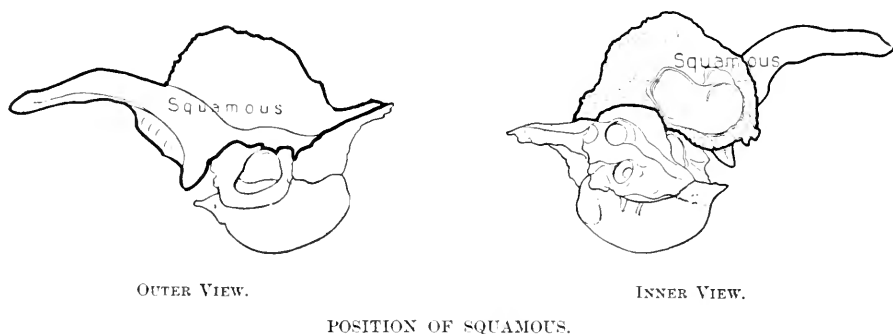


THE SKULL, LOWER ASPECT.

## THE SQUAMOUS PORTION.

The squamous portion (Fig. 128) is a thin, vertical plate of bone, about one-half longer than high, concave within and convex without. The upper border is arcuate, and the lower border is almost straight. It presents for examination an upper border and three surfaces, the external, the internal, and the lower.

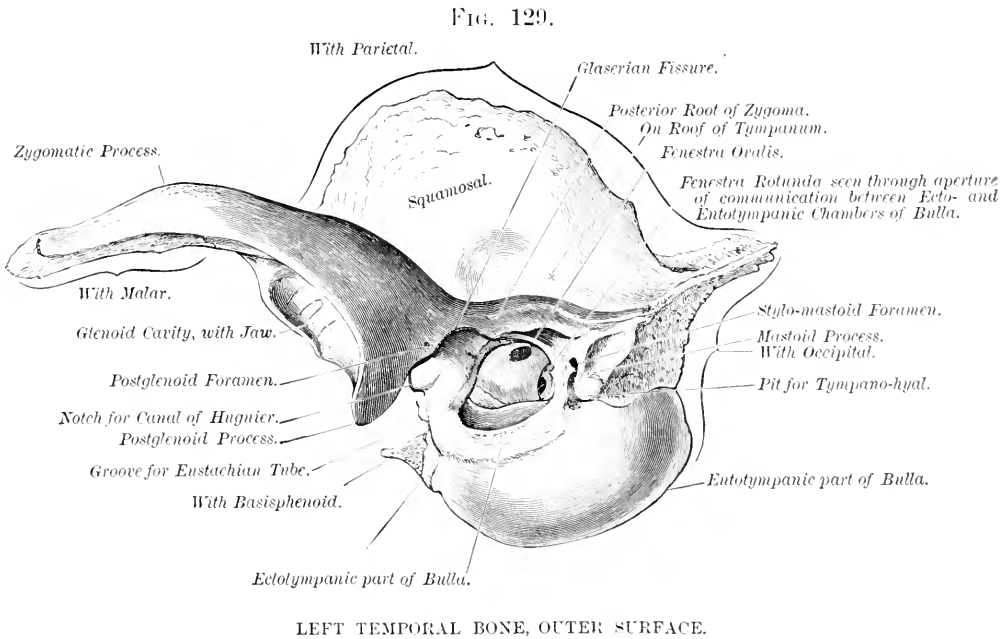
FIG. 128.



The **upper border** (Fig. 129) begins at the lower anterior angle, runs upward and slightly forward for a short distance, then arches upward and backward to reach the highest point at the junction of the anterior and middle thirds of the bone. From this point it arches downward with a less marked curvature, and just in front of the posterior border of the bone it turns at almost a right angle sharply upward and backward for a short distance, and terminates by forming the anterior border of a narrow process, whereof the end is jagged and the posterior border is parallel with the anterior and is continued downward and forward as the prolongation of the lambdoidal ridge on the occipital and separates the squamous from the mastoid. The free border is thin and sharp; for most of its length it is bevelled at the expense of the internal surface and overlaps the sphenoid and parietal.

The **external surface** is limited below by a well-defined, shelf-like ridge, which begins behind at the posterior limiting ridge and extends almost straight forward, arching upward slightly above the external auditory meatus, and is continued forward as the posterior and then the upper border of the zygomatic process. It is known as the posterior root of the zygomatic process. The surface is convex from before backward in its anterior higher half, and concave in its posterior half. The convexity is shorter and more marked below, just above

the zygomatic process, and longer and flatter at the upper border. From above downward, for the anterior third, the surface is also convex, more strongly in front of the zygomatic process; for the middle third, convex above and concave below; and for the posterior third, concave. In well-marked skulls a **temporal ridge** near the upper border, and parallel with it, marks the upper limit of the attachment of the fibres of the temporal muscle. The concavity above the posterior root of the zygomatic process is continued forward on the upper surface of the zygomatic process itself. It lies, for the most part, over the under surface of that root, a surface classed as part of the inferior surface of the squamous; but the part nearest the middle line of the skull is



thin and enters into the formation of the roof of the tympanum, forming more especially the roof of the deep fossa for the heads of the two ossicles of the ear known as the malleus and incus. Occasionally a small foramen is visible at the bottom of this concavity, but, as a rule, the external surface of the squamous is free from foramina.

The **zygomatic process** springs from the anterior lower angle of the external surface. Its heavy, basal portion is directed almost straight outward and slightly upward. It then narrows, turns sharply forward, and arches upward, forward, and inward to overlap the zygomatic process of the malar. It presents two surfaces and two borders,

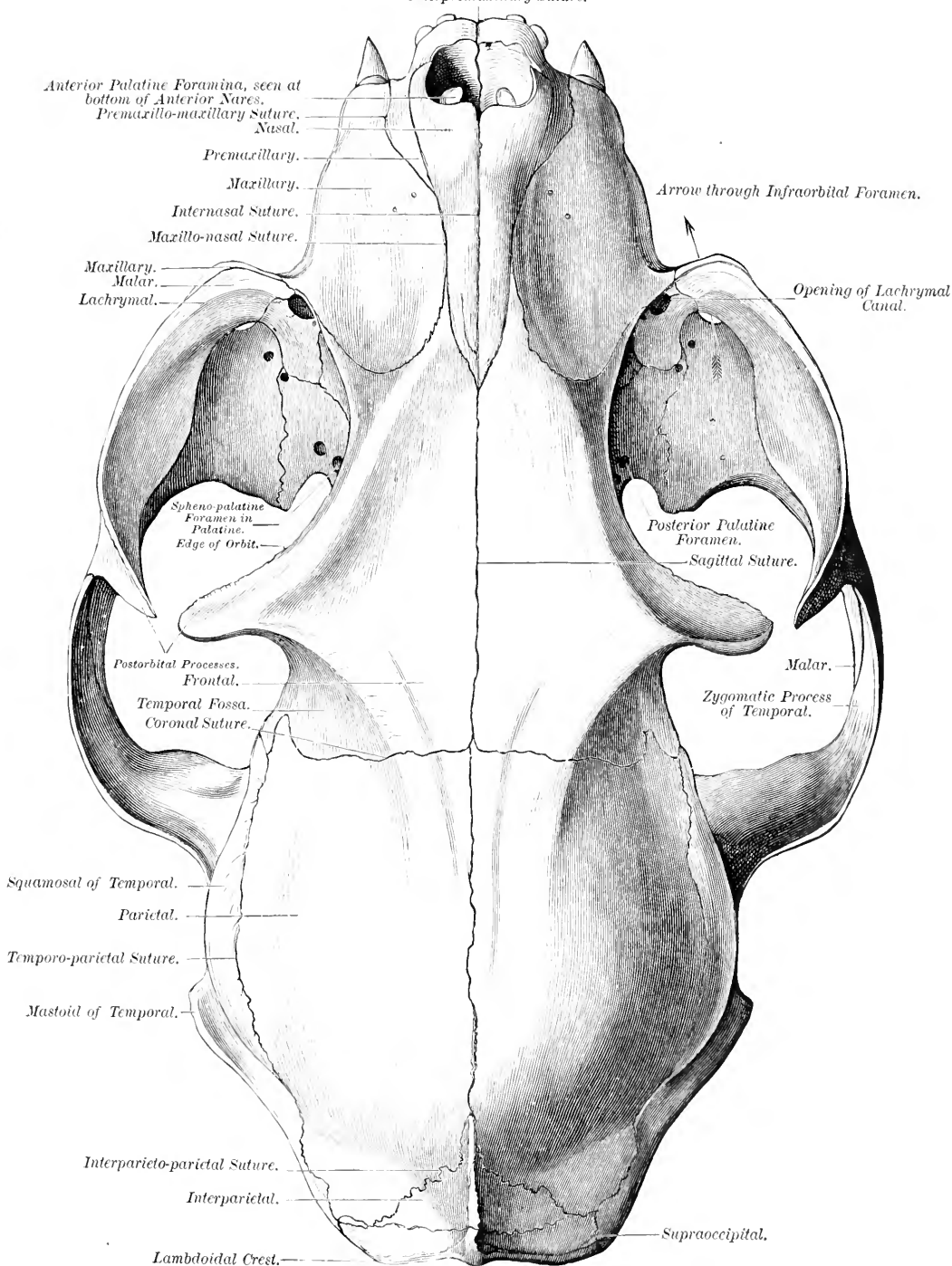
but the process is twisted on its own axis, at the bend which it makes to turn forward, in such manner that the superior surface of the basal portion becomes the internal surface of the extremity; the inferior surface becomes the external surface; the posterior border, the superior; and the anterior border, the inferior.

The **superior-internal surface** (Fig. 130) begins as a downward and outward prolongation of the anterior lower part of the external surface of the squamous. As the superior surface on the base of the process, it is broad, convex from before backward, faintly concave from side to side, and faces upward and forward. Its posterior part is grooved in front of the elevated posterior border. The anterior margin, which faces downward, is sharp and slightly emarginate within the triangular, downwardly directed, anterior glenoid process. It forms the anterior margin of the glenoid cavity. Beyond the glenoid cavity the zygomatic process becomes suddenly thin and narrow, and the superior-internal surface turns so as to face at first forward and inward and then almost directly inward. Its upper border is slightly arched, running upward and forward, but at a little distance from the end it becomes emarginate, presenting at that point a more or less prominent angle. The lower border follows in general the course of the upper border, but is straighter. It is bevelled at the expense of the outer surface and overlapped by the zygomatic process of the malar. As the internal surface of the end of the process, it is strongly concave from before backward and gently concave from above downward. The masseter muscle has origin on its lower anterior part.

The inferior-external surface (Fig. 131) of the thick basal portion of the process is a continuation outward and slightly forward of the lower surface of the squamous. It is divided into anterior and posterior parts by a transverse **postglenoid process**.

The anterior part in the **glenoid cavity** is about three times as wide as it is long from before backward; it is concave from before backward, and faces downward and largely forward. Its inner end is flattened, and is continuous with the region of the alisphenoid just external to the foramen ovale (Fig. 127). Its outer narrow end is cut off obliquely behind by the forwardly arching posterior border. Its anterior margin is well defined and slightly prominent at the inner end, and produced downward at its outer end into a conspicuous

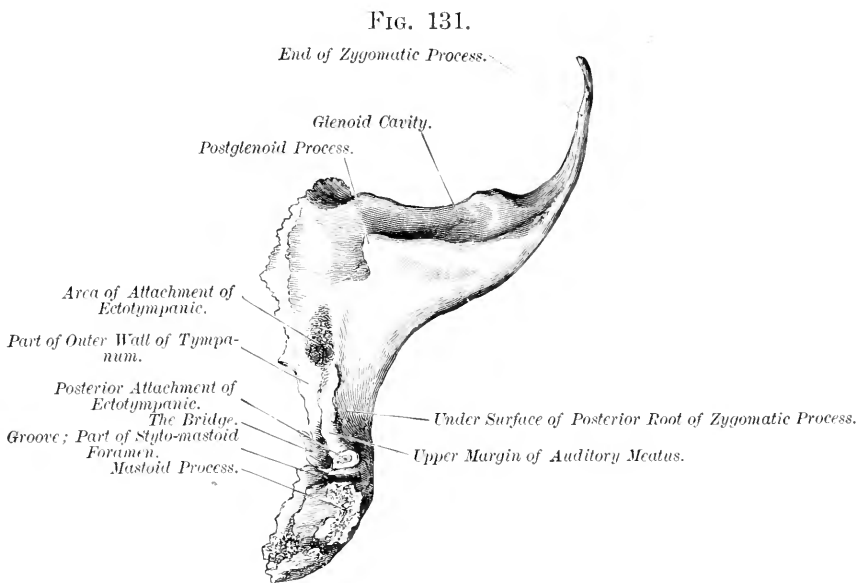
FIG. 130.

*Interpremaxillary Suture.*

THE SKULL, FROM ABOVE.

**anterior glenoid process.** The posterior margin is produced downward and forward at the inner end into the triangular postglenoid process. The glenoid cavity is lined with cartilage, and receives the condyle of the lower jaw. In front of the glenoid cavity, and on the outside of it, the lower surface of the zygomatic process is continuous with the posterior-inferior border.

The posterior part of the inferior-external surface of the zygomatic process is behind the postglenoid process, and continuous with the under surface of the posterior root of the zygoma. It is smooth and irregularly convex from behind forward. It faces backward and



INFERIOR SURFACE OF SQUAMOUS PORTION OF TEMPORAL BONE; THE PETROUS  
AND TYMPANIC PORTIONS REMOVED.

downward at its beginning; then backward, downward, and outward; then outward, and at the extremity also outward and slightly forward, there being no break between the stout basal portion and the slender extremity. It is higher behind, in the region of the postglenoid process, and narrower in front of the region of the glenoid cavity, inasmuch as from that point its lower border is bevelled and overlapped by the malar, as already mentioned. Just behind the inner end of the postglenoid process is a **postglenoid foramen**, more or less well marked, which transmits a vessel from the diploë.

The **inferior surface** of the squamous (Fig. 131) is little more than a border separating the external and internal surfaces. For the first



quarter it is the continuation inward, toward the middle line, of the glenoid cavity, and its inner edge is rough, bevelled, and overlapped by the alisphenoid. In the rest of its extent three narrow regions may be distinguished,—namely, (*a*) an outer region, which lies outside the auditory meatus; (*b*) a middle region, which enters into the formation of the rim of the auditory meatus; and (*c*) an inner region, which lies within the auditory meatus and enters into the formation of the tympanum.

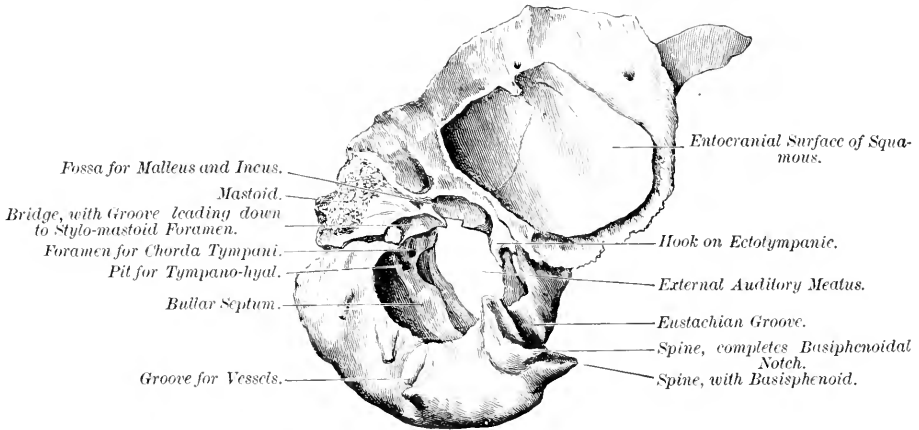
(*a*) The **Outer Region**.—The surface behind the postglenoid process on the outside arches upward as the under surface of the posterior root of the zygoma. This part is wider in front than behind, where it fades out on the outer surface of the mastoid. Its outer margin is emarginate for the anterior half and nearly straight behind. It is concave from side to side as well as from before backward, and faces downward and outward.

(*b*) The **Middle Region**.—On the inner side of the anterior end of the under surface of the zygomatic root, just behind the postglenoid foramen, is a depressed **oval area**, whereof the long axis is directed obliquely backward and inward. Its posterior part is rough, where the anterior end of the ectotympanic of the bulla is attached. Behind this area is a rounded ridge, which arches slightly upward and is directed outward and backward, sometimes straight, sometimes emarginate externally. It forms the middle part of the upper margin of the external auditory meatus, while all the rest of the bone surrounding the orifice is contributed by the ectotympanic of the bulla. This middle region terminates behind in a circular, roughened point of attachment for the posterior upper end of the ectotympanic. Behind this point, and separating the lower surface of the squamous from the mastoid process, is a transverse groove, which, meeting a notch in the bulla between the ends of the ectotympanic and entotympanic, is converted into the stylomastoid foramen.

(*c*) The **Inner Region**.—The strip which is within the margin of the auditory meatus consists of three parts. In front, just within the oval depression for the attachment of the ectotympanic, is a small area, wider in front than behind, and bounded in front by a line drawn inward from the postglenoid process, on the outside by the elevated oblique inner margin of the oval depression, and on the inside by a straight, longitudinal, serrated border, which is

overlapped by the posterior portion of the outer border of the alisphenoid. This area faces downward and backward, and is covered by the inner part of the upper anterior end of the ectotympanic, which does not touch it, however, in all places, thus forming the Glaserian<sup>1</sup> fissure. A distinct groove in its outer part is converted into the canal of Huguier.<sup>2</sup> The rest of the lower surface within the auditory meatus might be almost called a portion of the inner surface of the squamous (Fig. 132), inasmuch as it faces almost

FIG. 132.



LEFT TEMPORAL BONE. INNER SURFACE. PETROUS PORTION REMOVED.

directly inward and only slightly downward. It is about twice as long as high. It forms the upper part of the outer wall of the tympanum, and is impressed by two fossæ. The larger, upper, and anterior fossa lodges the heads of the malleus and incus. It is oval, the long axis running longitudinally. Its sharp, elevated, upper border joins the anterior border of the petrous portion of the temporal, and the rough space for the ectotympanic attachment limits it in front. Below, it is bounded in part by the emarginate, rounded border of the auditory meatus, and in part by a longitudinal convexity which separates it from the second fossa. It faces directly inward. The second fossa lies below and behind the first. It is smaller, almost round, and contains the superior process of the incus. It faces downward and inward. Its upper anterior limit is the convexity already mentioned, due in reality to the difference between its plane and that of the other fossa. The anterior and lower boundary is, in front, the

<sup>1</sup> Glaser (A.D. 1629–1675).<sup>2</sup> Huguier (A.D. 1804–1874).

posterior part of the auditory rim, and behind it is the rough edge left by breaking off the posterior attachment of the ectotympanic part of the bulla. It is bounded posteriorly and on the inside by the anterior surface of a small, thin, and sharp plate or shelf, which runs upward and forward and slopes inward and forward so as to end above in a pointed process which joins the petrous just above the fenestra ovalis, and may be named, for convenience, the **bridge**. This plate ends, below, where the free upper edge of the ectotympanic ends, and where the posterior root of the septum of the bulla begins. The posterior inner surface of this plate is concave transversely, and, with its continuation,—namely, the deep distinct groove which curves downward, backward, and outward behind it,—is converted by the bulla into a canal, the lower portion of the aqueductus Fallopii.<sup>1</sup> This canal separates the squamous from the mastoid.

The **internal surface** of the squamous has the general outline of the external surface. It possesses a boldly arched upper border, which curves downward before and behind to meet the almost straight, longitudinal, lower border. The surface is concave, the deepest part of the concavity lying in front of and below the centre of the bone, not much above and behind the lower anterior angle. This point is the centre of an almost smooth circular area, which enters into the formation of the inner surface of the cranium, contributing the lower part of the side of the middle cerebral fossa. It is often marked by grooves for the meningeal artery, whereof the most constant appears to be a vertical groove near the posterior part. The part of the surface lying below and in front of this area is a narrow rough strip, slightly bevelled along the front and lower borders, which joins the outer side of the alisphenoid and the alisphenoidal root of the tentorium. A wider, thinner, bevelled band lies at the upper and back part of the inner surface and overlaps the parietal and joins the outer edge of the parietal root of the tentorium. The upper part of the base of the petrous portion of the bone is firmly coalesced with the posterior part of the lower border and the posterior lower angle of the inner surface of the squamous, at which point the squamous also unites with the mastoid. When the petrous is broken away, the whole inner surface of the mastoid is exposed, as well as the inner and the posterior part of the lower surface of the squamous.

<sup>1</sup> Fallopius (A.D. 1523–1562).

## THE PETROUS PORTION.

The petrous portion (Fig. 133) is easily distinguished by its dense, white, glistening appearance, and is free from the other portions except at its posterior outer part, or base, where it cannot be readily separated from the squamous and mastoid. It is concealed on the base of the skull by the auditory bulla, although a part of its surface may be seen by looking through the auditory meatus. In the interior of the skull it can be easily recognized lying at the side under the lower end of the tentorium.

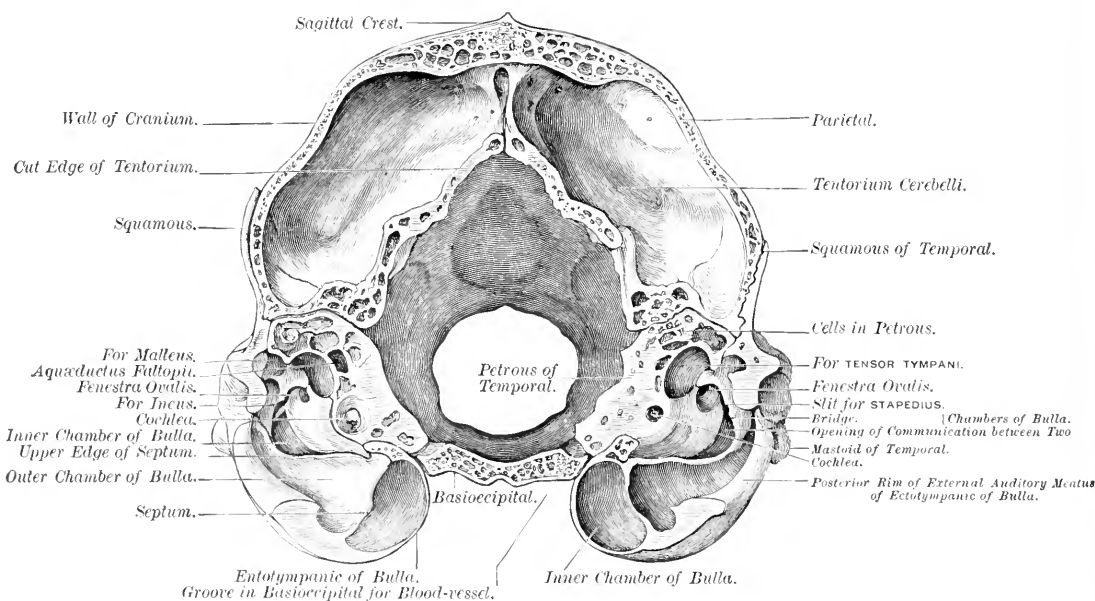
Fig. 133.



INNER VIEW.  
POSITION OF PETROUS.

The petrous has the form of a prostrate pyramid, whereof the base faces outward, upward, and backward and the apex points downward, forward, and inward. Of the three surfaces the posterior and the inferior are large and pear-shaped and about equal in size, while

Fig. 134.

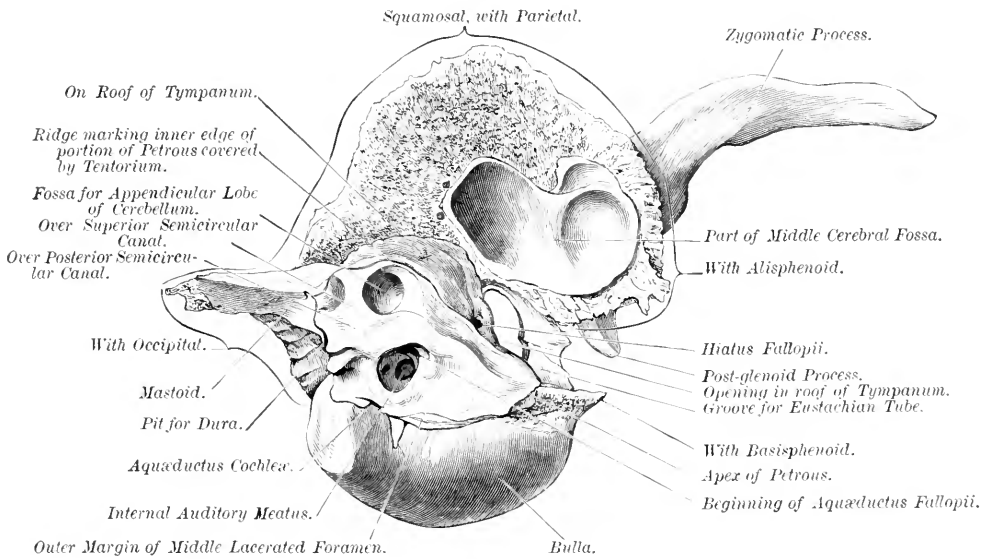


TRANSVERSE VERTICAL SECTION OF SKULL THROUGH EXTERNAL AUDITORY MEATUS.

the anterior is only about half as wide as each of the other two. The petrous is so placed that the anterior surface, which is almost entirely covered by the lower part of the under surface of the tentorium, faces forward, upward, and outward; the posterior surface faces backward,

upward, and inward; and the inferior surface faces downward, forward, and outward. These surfaces are separated by three borders,—the posterior border, which joins the outer edge of the basilar plate of the occipital; the anterior border, which joins the basisphenoid, the alisphenoid, and the squamous portion; and the superior border, which is in part applied to the under surface of the tentorium and in part exposed in the cranial cavity (Fig. 134). The apex of the petrous overlaps the inner posterior cranial portion of the basisphenoid at the large lateral notch. The posterior surface is the only one plainly visible in the cranial cavity, where it assists in the formation of the sides of the posterior cerebral fossa.

FIG. 135.



LEFT TEMPORAL BONE, INNER ASPECT.

The posterior surface (Fig. 135), although marked by depressions and elevations, lies all in one plane. Its general outline is triangular, and it is nearly twice as long as it is wide. The base of the triangle lies above and behind, against the squamous and mastoid; its sides are the anterior and posterior margins. The anterior margin is arcuate or slightly sinuate, and well defined for the outer two-thirds and faintly emarginate for the inner third, where the posterior and anterior surfaces pass into each other. The posterior margin is gently arcuate, especially at the apex of the surface, which thus appears turned slightly outward. For most of its course the posterior boundary is in contact with the basioccipital and faces as much inward as back-

ward, but at the basal angle it is truncated, giving rise to a short, jagged portion, which faces directly backward and forms the anterior boundary of the groove for the lateral sinus. The basal or superior margin of the surface is not always clearly defined, but usually may be distinguished as an elevated semicircular line separating the denser petrous from the more porous mastoid. The most striking feature on the posterior surface is the foramen for the transmission of the facial and auditory nerves to the interior of the bone, known as the **internal auditory meatus**. This foramen lies behind and below the centre of the surface; its general outline is oval, the long axis running nearly parallel with the long axis of the skull, but forming an acute angle with the long axis of the surface. On examining the foramen more closely it is seen that, while its surrounding ridge is oval and more elevated behind, its real outline is that of an inverted comma. The large posterior round part receives the auditory nerve, and the small anterior curved tail is the beginning of the canal for the facial nerve,—namely, the **aquæductus Fallopii**, which winds through the substance of the petrous, then between the petrous, mastoid, and squamous, and opens on the outside and base of the skull at the stylomastoid foramen.

If the internal auditory meatus be examined more closely, its two parts will be seen to be divided by a distinct longitudinal ridge (Fig. 136). The lower part, for the auditory nerve, does not go all

FIG. 136.

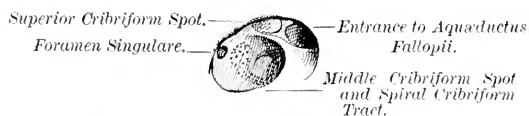


DIAGRAM OF LEFT INTERNAL AUDITORY MEATUS.

the way through the bone; it is a deep pit, directed forward and inward, and, becoming somewhat smaller as it proceeds inward, terminates as a circular plate.

The posterior wall of the pit and this circular end-plate form the **lamina cribrosa**, which separates the meatus from the labyrinth within. On the posterior wall is seen a small opening, the **foramen singulare**, which leads to a canal, the posterior wall of which is perforated by small holes, producing the **inferior cribriform spot** and transmitting nerves to the lowest ampulla in the vestibule. In the lamina cribrosa, in front of the foramen, is a depressed circular area, also sieve-like, known as the **middle cribriform spot**, which transmits nerves to the fovea hemispherica of the vestibule. From this area a perforated

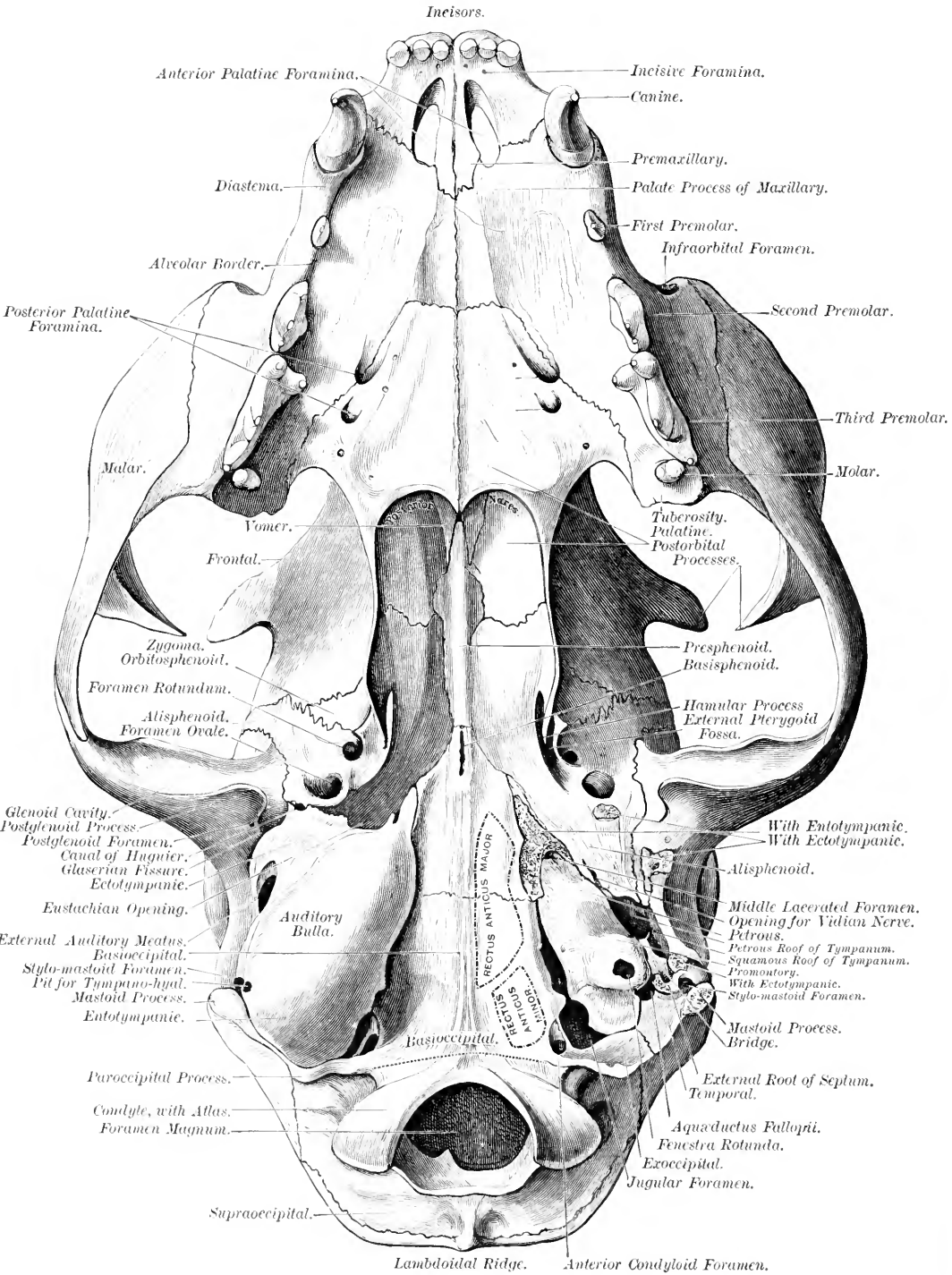
band winds spirally around the wall of the auditory pit and terminates in the circular plate in front. This band constitutes the **spiral cribriform tract** and transmits nerves to the cochlea. The facial canal begins as a deep groove in the anterior wall of the auditory meatus, and runs upward and backward and enters the petrous by a wide opening under the overhanging upper auditory rim. At this point is another deep pit, the porous floor of which constitutes the **superior cribriform spot**, seen in the fovea hemielliptica of the vestibule. The progress of the facial canal through the bone will be traced hereafter.

Near the upper basal angle of the surface, and separated from the internal auditory meatus by a rounded oblique bony ridge, is a large **deep fossa**, which receives the appendicular lobe of the cerebellum. It is irregularly triangular. Its anterior boundary is the upper part of the sharp superior border. Its posterior and upper wall is formed by a prominent oblong swelling, which marks the position within the bone of the **superior semicircular canal**. Behind and above this swelling, occupying the region as far as the upper edge of the surface, is often found a shallow groove. The continuation backward of the convex surface lying between the appendicular fossa and the internal auditory meatus marks the position within the bone of the **posterior semicircular canal**. Where this ends, on the posterior border is a cleft, which penetrates the bone deeply, affords attachment to a fold of the dura mater, and leads into the internal ear through the aquæductus vestibuli. The remaining portion of this surface is concave from above downward in front and behind the auditory meatus, and slightly convex from above downward along the posterior border.

The **anterior surface** of the petrous (Fig. 138) is also triangular, but much narrower than the other two surfaces. It is at least three times as long as it is wide at the widest place, near the outer basal border. It consists of two well-defined parts: (*a*) an outer and posterior prominent quadrate portion, and (*b*) an inner, anterior, depressed triangle. Where the two regions join is seen a small slit-like or rounded foramen, known as the **hiatus Fallopii**, which leads into the facial canal or aquæductus Fallopii.

(*a*) The outer, prominent part of the surface is convex from without inward, and marked by a faint arborescent groove running up from the hiatus Fallopii near the anterior border. It is quadrate

FIG. 137.

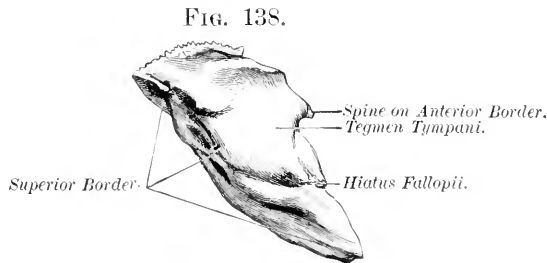


THE SKULL, LOWER ASPECT.



in outline, the anterior and posterior borders being straight and parallel. The outer border is slightly arcuate, and the outer anterior angle rounded. Just in front of this angle, on the anterior border, is a more or less prominent **spine** or hook, which marks the anterior limit of the articulation of the petrous with the squamous, and also the outer boundary of a vacuity in the roof of the tympanum between the petrous, the ectotympanic, and the entotympanic, which is exposed by the removal of the overlying bony tentorium (Fig. 135). This region of the surface lies directly over the tympanic cavity, and especially that part which contains the tensor tympani muscle, and is known as the **tegmen**<sup>1</sup> **tympani**.

(b) The inner, small, triangular portion of the anterior surface is depressed and concave from before backward and from without



PETROUS PORTION OF TEMPORAL BONE. ANTERIOR SURFACE.

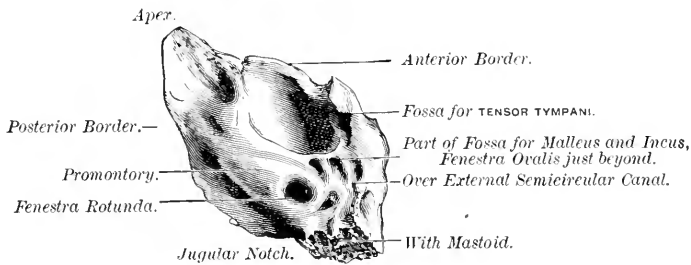
inward. Its base is at the hiatus Fallopii; its sharp upturned apex is the apex of the entire bone. Its anterior border is arcuate and sharp, but posteriorly it passes without break into the posterior surface. It supports the Gasserian ganglion on the fifth cranial nerve, and is the only part of the anterior surface visible in the cranial cavity, as it is not covered by the tentorium.

The **inferior surface** of the petrous (Figs. 137, 139) is wider and shorter than the posterior surface. It is triangular or pear-shaped. The inner boundary is the posterior border of the bone. This tends almost directly from before backward, and turns outward at the posterior end. Its anterior end is covered by the basisphenoid. For its anterior two-thirds it is gently sinuate, and lies near the outer edge of the basilar plate of the occipital. The posterior third is emarginate, often very deeply, to form with the occipital the jugular

<sup>1</sup> A roof.

foramen. The posterior inner angle is rounded, and abuts against the exoccipital. The posterior outer boundary of this surface is arcuate, and is united with the mastoid and squamous. The union with the

FIG. 139.



PETROUS PORTION OF TEMPORAL BONE. INFERIOR SURFACE.

mastoid is short, but complete; that with the squamous embraces fully the outer half of the border and can be easily broken, leaving a nearly straight, sometimes even slightly emarginate, edge. The posterior outer angle is almost a right angle, and is slightly rounded.

The anterior external boundary is the anterior border of the bone. This is directed from without obliquely inward and forward to meet the posterior border at the apex. It presents three nearly equal parts. The first of these is the sharp outer third; it articulates with the squamous and extends from the angle to the tip of the spine already mentioned as visible on the front edge of the anterior surface. Internal to this portion is a middle third, nearly straight, rounded and inverted, and directed slightly more transversely to the axis of the bone; it articulates with the alisphenoid. A decided **notch** for the passage of the Vidian nerve separates this middle third from the inner third, which is again sharp and takes the same direction as the outer third, and articulates with the basisphenoid.

The inferior surface is convex in both directions in such manner that, while the inner part faces almost directly downward, the outer part faces outward and downward, and, while the anterior part faces downward and slightly forward, the posterior outer part faces downward and backward. The most striking feature on this surface is the prominent central swelling, the **promontory**, caused by that part of the internal ear called the cochlea. The promontory is ovoid, about twice as long as it is wide; its long diameter lies slightly to the inner side of the long axis of the surface and parallel to it, and is about half

as long as the surface itself. Posterior to this point is a nearly circular opening called the *fenestra rotunda*, or round window, which faces outward, backward, and upward and opens into the base of the cochlea. The promontory is crossed just in front of its highest convexity by a faint, oblique groove which is directed transversely to the long axis of the skull. The highest part of the promontory, behind this groove, marks the large first whorl of the cochlea; the lower, smaller part in front of it contains the two smaller whorls.

The region of the inferior surface within and behind the promontory, beginning at the notch for the Vidian nerve on the anterior border and extending as a strip along the inner border, is slightly concave transversely and is applied to the upper surface of the introverted plate of the entotympanic, which forms part of the roof of the larger medial chamber of the bulla. The promontory itself displays along its long axis a slight flattening, which marks the place where it rests on the septum of the bulla. On its outer face, which forms part of the roof of the outer or smaller chamber of the bulla, the true tympanum, are grooves for the tympanic plexus of vessels and nerves. Only a portion of the petrous is seen as the roof of the inner or medial chamber of the bulla, and this is the inner and posterior part of the promontory.

The remaining part of the inferior surface of the petrous lies on the outer side of the promontory, and enters into the formation of the roof of the tympanum. It is triangular, bounded in front by the basal portion of the anterior border, which joins the alisphenoid, and behind by the basal border, which joins the squamous. Occupying the anterior half is a deep, oblong, oblique *fossa*, which contains the tensor tympani muscle. An arcuate, transverse, elevated line separates this fossa behind from three features,—a foramen, a bony bar, and a fossa.

The *foramen* lies to the medial side on the outer wall of the promontory, and is called from its shape the *fenestra ovalis*, or oval window. Its long axis is directed from before backward, and it faces almost directly outward. In the macerated skull it opens into the vestibule of the inner ear, but in the natural state it is occupied by the base of the stapes, one of the ossicles of the ear.

On the outer side is a somewhat crescentic and slightly concave area, which, with the concavity on the under surface of the squamous,

forms the **fossa** for the heads of the remaining ear-ossicles, the malleus and incus.

Behind these two features, firmly attached to the middle of the curved posterior border of the tensor tympani fossa, is the inner end of a bony **bridge**, which is a continuation inward, forward, and upward of the end of the plate which forms the posterior upper wall of the smaller fossa on the under surface of the squamous. When this bar is broken away, just above it and behind its point of attachment to the petrous is seen the slit-like opening of the aquæductus Fallopii. This opening is continued downward and inward as a short, curved groove, which in turn is continuous with the groove between the petrous and the mastoid, and, as has been already described, is converted into the extrapetrous portion of the aquæductus Fallopii by the concave posterior inner surface of the bridge projecting from the squamous, and by the groove between the posterior ends of the eectympanic and entotympanic.

A narrow, slightly crescentic fossa lies behind and to the medial side of the groove on the petrous, separated from it by a ridge which contains the anterior end of the **external semicircular canal**. The stapedius muscle is lodged in this fossa, and enters the tympanum through the slit which is visible between the promontory and the thin inner edge of the bony bridge from the squamous. This fossa is practically the posterior limit of the inferior surface of the petrous. Its long axis is directed from within outward and forward. Its anterior wall is convex, and is the posterior outer wall of the vestibule contained in the petrous. Its posterior wall is concave in both directions, and contains near its upper margin the greater part of the external semicircular canal.

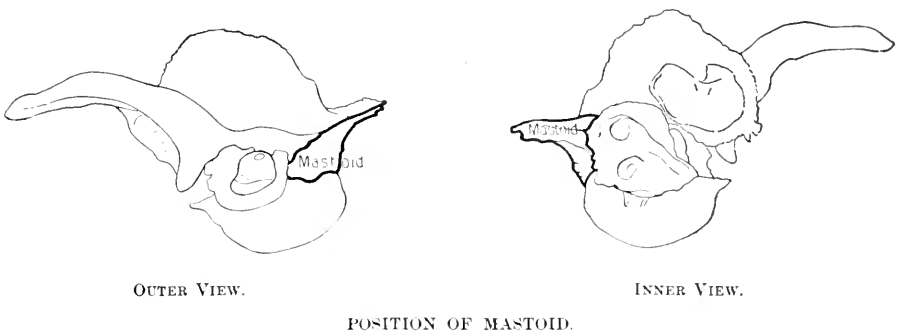
The **anterior border** of the petrous (Fig. 138) separates the anterior and inferior surfaces. It is directed from without inward and forward. It consists of three equal parts. The middle part is directed slightly more transversely to the long axis of the skull than the outer and inner portions, from which it is separated on the outside by a hook, on the inside by a groove leading to the hiatus Fallopii on the anterior surface. It is rounded, forms the anterior margin of the fossa for the tensor tympani on the inferior surface, and articulates with the alisphenoid. The outer part of the anterior border is sharper, passes into the basal borders of the anterior and inferior surfaces, and articu-

lates with the squamous. The inner part of the border is sharp and arcuate, overlaps the cranial surface of the basisphenoid, and joins the other two borders of the petrous at the apex.

The posterior border (Fig. 139) has the same general direction as the other borders, but is more nearly longitudinal. It presents an upper and a lower sharp edge, and with the contiguous border of the occipital forms a groove for the lower petrosal sinus. It is arcuate, especially in front. Behind it is notched to assist in forming the jugular foramen. A short distance in front of the jugular notch is the small slit-like opening of the *aquæductus cochleæ*, which leads into the internal ear. The border lies against the lateral border of the basioccipital, the cranial surface of which it slightly overlaps in front.

The superior border of the petrous (Fig. 135) is seen in the cranial

FIG. 140.



cavity of the skull in its completeness when the tentorium, which covers its outer two-thirds, is broken away. It is directed from without obliquely inward, forward, and downward. In the outer two-thirds it is elevated and arcuate forward, and separates definitely the anterior and posterior surfaces. The inner third is low and concave, permitting the two surfaces to pass into each other. The superior border meets the posterior and anterior borders at the apex of the bone, and, behind, forms an acute angle with the basal border of the anterior surface and almost a right angle with the corresponding border of the posterior surface. The superior border gives attachment to the dura mater, in which is included the superior petrosal sinus.

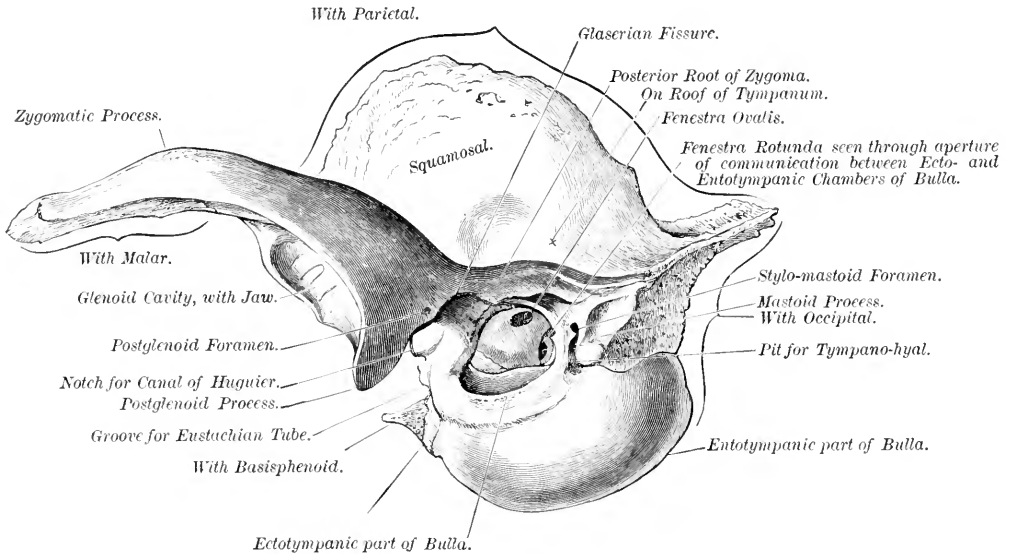
#### THE MASTOID PORTION.

The mastoid lies at the back of the temporal bone, behind and below the squamous, behind and lateral to the petrous, and above and

behind the bulla (Fig. 140). It articulates behind with the exoccipital part of the occipital. It presents an external, an internal, and a posterior surface.

The **external surface** (Fig. 141) is a narrow strip, prolonged below into a rounded prominence, the mastoid process proper. The long axis of the external surface is directed downward and forward. The surface is sharply defined, and is separated from the squamous in front by a prominent ridge, the continuation downward of the lambdoidal ridge which meets the posterior end of the posterior root of the zygoma, and is thence continued to the stylomastoid foramen. It affords attachment to the lower parts of the sternomastoid and splenius

FIG. 141.



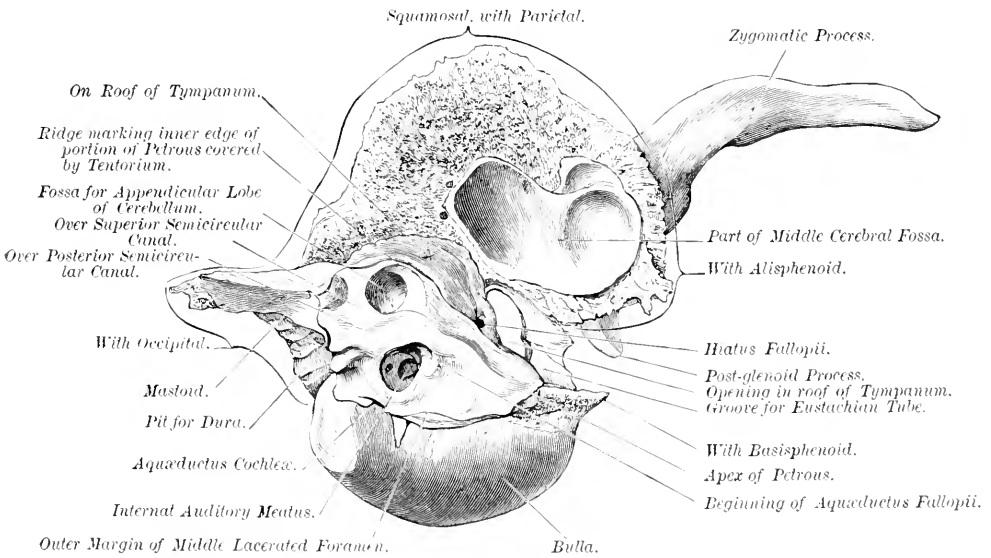
LEFT TEMPORAL BONE, OUTER SURFACE.

muscles. The posterior edge of the external surface is also directed downward and forward, and consists of an upper and a lower half. The upper half is quite straight and jagged, and forms the outer edge of the posterior surface joining the occipital. The lower half forms an obtuse angle with the upper half; it is directed forward and is sinuate. Its upper part is sharp and applied to the bulla, and gives origin to the styloglossus muscle. The lower part is rounded into the back of the mastoid process, to which the cleidomastoid is attached. The **mastoid process** is small, convex, and marked by an irregular groove in front of its long axis, from which the trachelomastoid muscle

ris. It is obtusely rounded below and is closely applied to the bulla, from which, however, it is separated in front by the stylomastoid foramen. Its end lies just over the pit in the bulla for the tympanohyal. The external surface is gently concave from before backward, and faces outward and slightly backward. It is roughened, and gives origin for most of its extent to the rectus capitis lateralis muscle.

The posterior surface of the mastoid (Fig. 142) is of small extent and limited to the upper half of the bone. It is triangular, excavated, and roughened, faces inward, downward, and backward, and articulates with the lower part of the lateral border of the occipital. Its lower outer angle is continued down as the thin posterior border of the mastoid process, separating the external and internal surfaces. The upper angle is continued upward as a roughened border of varying extent and width, which articulates with the thinner part of the lateral border of the occipital. The inner lower angle is continuous with the posterior border of the petrous. The outer border is almost

FIG. 142.



LEFT TEMPORAL BONE, INNER ASPECT.

straight, and is directed upward and inward; the lower border is emarginate, and is directed inward and slightly upward; the inner border is irregular, and is directed upward and outward.

The inner surface of the mastoid consists of three parts: (1) A small upper part (Fig. 142), the only portion which appears in the cranial cavity. It is a narrow strip running upward and backward

from the base of the petrous, articulating by its irregular emarginate anterior border with the lower part of the posterior border of the parietal, and by the short rounded upper border with the occipital. The posterior border is also the inner border of the posterior surface of the mastoid. This portion is concave in both directions and supports the lateral sinus.

(2) Below and in front of this portion is a small irregular area whereby the petrous completely coalesces with the mastoid (Fig. 132); an attempt to break the two portions apart usually produces a fracture through the mastoid and opens up the mastoid cells in the cancellous tissue.

(3) The third or lower portion of the inner surface of the mastoid lies below the preceding; it faces inward, downward, and forward, and is applied to the outer posterior part of the entotympanic of the bulla (Fig. 137). It is triangular in form, smooth, and concave; the lower, rounded angle is directed forward and downward, and is the end of the mastoid process proper. A sharp ridge passing upward and backward from this angle separates this surface in front from the groove with the same direction which lies between the mastoid, the upper end of the ectotympanic, and the lower posterior part of the squamous, and, when completed by the groove on the bulla, forms the terminal portion of the aquæductus Fallopii. The upper anterior angle is truncated, and meets the posterior part of the basal portion of the inferior surface of the petrous. The upper border is also the lower border of the posterior surface; the posterior border is common to the external surface.

#### THE AUDITORY BULLA.

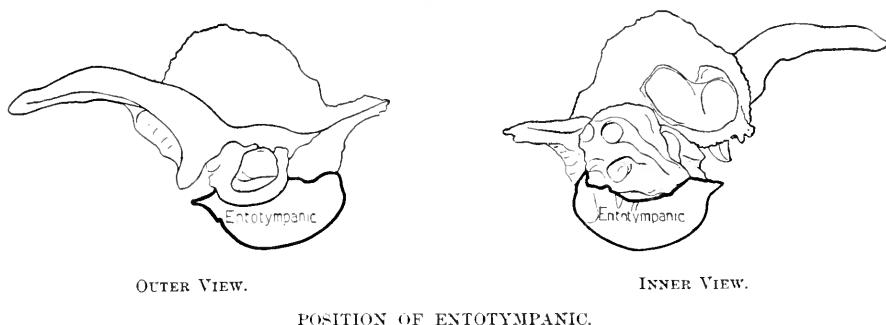
The auditory bulla is an oblong sac, whereof the upper, free rim, or mouth, is applied to the base of the skull, covering in completely the petrous and the adjoining edges of the squamous and mastoid portions and the edges of the exoccipital, basioccipital, basisphenoid, and alisphenoid. It is not firmly united to the skull, and is readily broken free from its attachments with the sphenoid and squamous in front and with the occipital and squamous behind.

When removed from the skull it is seen to be composed of two parts, an inner, thin-walled, entotympanic part, and an outer, denser, ectotympanic part. Of these the entotympanic part (Fig. 143) is



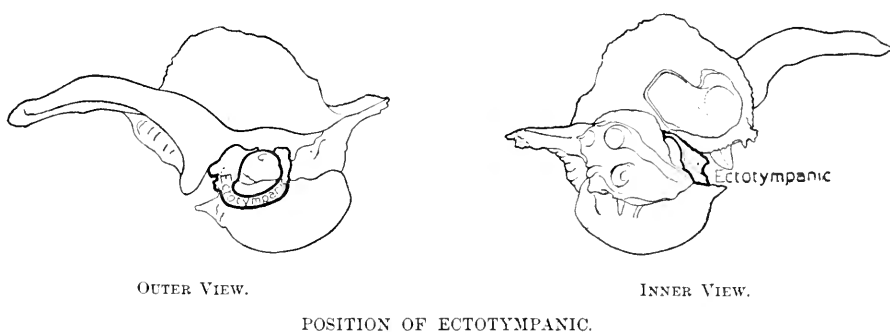
by far the larger, forming almost all of the bulla. It is regularly oval; pointed in front, and rounded behind. The ectotympanic (Fig. 144) is a bony ring surrounding the external auditory meatus and applied to the outer side of the entotympanic. It is not a complete ring; a short segment is wanting at the upper posterior part. As the ectotympanic is wider in front above, where it turns backward to join

FIG. 143.



the skull, than it is where it coalesces with the entotympanic below the auditory meatus, it appears to be united to the entotympanic at an angle, with its plane directed upward and outward from the plane of the entotympanic. It will be noticed, also, that the anterior outer part of the flattened rim of the bulla, applied to the skull, the part which is supplied by the ectotympanic, is higher than the rest and

FIG. 144.



faces more obliquely outward and forward. The bulla, as a whole, presents an external and an internal surface and a superior border which is introverted and so wide that it may be termed a superior surface.

The **external surface**.—The external surface of the entotympanic

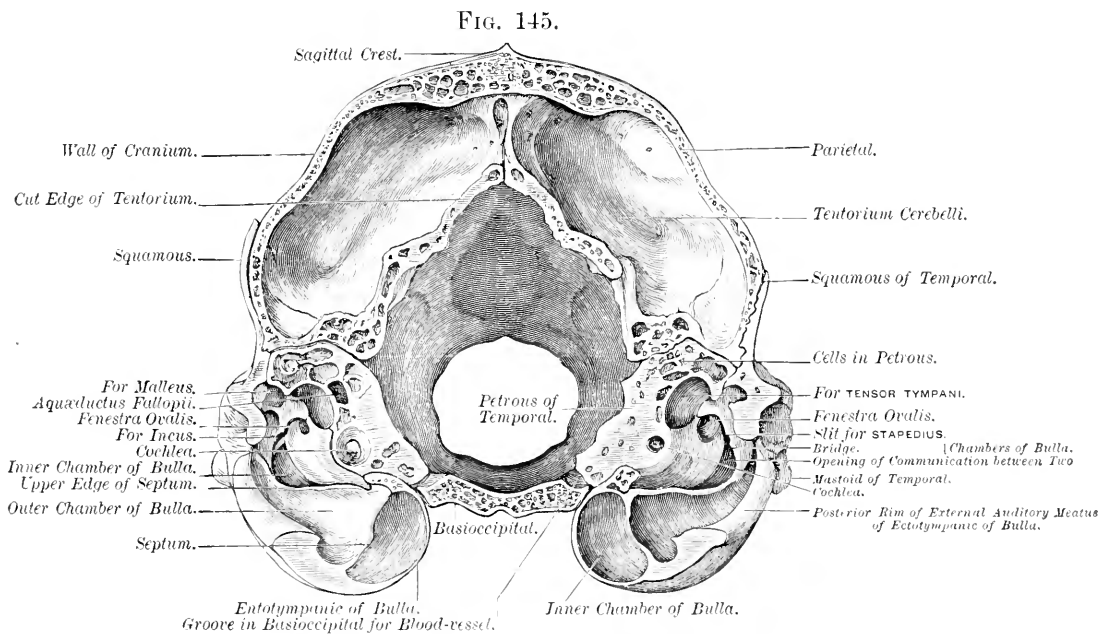
(Fig. 137) is egg-shaped, smooth, and transparent. It is sometimes marked by faint, oblique grooves which indicate thickenings or partial septa on the internal surface. The anterior end is prolonged into a sharp **spine** which joins the under surface of the sphenoid between the basisphenoid and the alisphenoid. The internal edge is slightly arcuate, and is impressed, behind the middle, by one or more faint vertical grooves which may be deepened into canals. Behind these grooves is a slight emargination for the anterior outer wall of the jugular foramen. The posterior end is rounded and exhibits two roughened places for attachment to the paroccipital process of the occipital and to the mastoid. Between the entotympanic and the ectotympanic, behind, is a **groove** which forms the inner wall of the stylo-mastoid foramen and the terminal portion of the extrapetrous part of the aquæductus Fallopii. Just on the inner side of this foramen is the deep **pit** for the tympano-hyal bone. The outer boundary of the entotympanic is the line where the rougher and harder ectotympanic has become fastened to it. The line is about parallel with the long axis of the bulla, but curves upward in front and behind. Its course is marked by numerous small foramina. Between its anterior end and the spine on the front of the bulla is a very short slightly emarginate anterior boundary which contributes to the inner part of the lower margin of the **Eustachian opening**. A minute spine near its inner part assists in forming a small notch.

The shape of the external surface of the **ectotympanic** (Fig. 141) is almost that of a ring. Its width is about the same in all parts, except in front, where it is prolonged to an angle. It is narrowest behind, where it appears to spring from the squamous as a round column in front of the stylo-mastoid foramen. It has a distinct, arcuate and slightly sinuate, anterior outer and upper margin, which abuts against the squamous and is directed, from behind, forward and then downward and inward. It forms the lower margin of the Glaserian fissure; near its middle is a notch for the canal of Huguier. At its inner end, forming nearly a right angle with it, is a short anterior upper and inner margin which is directed inward and backward to meet the front margin of the entotympanic. This part of the border is emarginate and forms the lower part of the Eustachian opening. The external surface of the ectotympanic faces outward and somewhat downward, and in front also forward. It is rough and

slightly convex; it arches downward, forward, and inward. The rim of the external auditory meatus is formed by the ectotympanic, with the exception of a small area at the upper posterior part, which is derived from the squamous. The rim is moderately sharp, and often slightly serrated at the anterior, lower end. A notch at the upper posterior part indicates the point at which, on the inner surface, the septum of the bulla begins.

The auditory meatus is irregularly egg-shaped, and almost twice as long as it is high. It is rounded behind and pointed in front; the long axis is directed, from behind, obliquely downward and forward. The external ear is attached near the rim of the meatus, and principally to the ectotympanic.

The interior of the bulla is divided into two chambers by a bony septum (Figs. 145, 146) attached along a line indicated on the

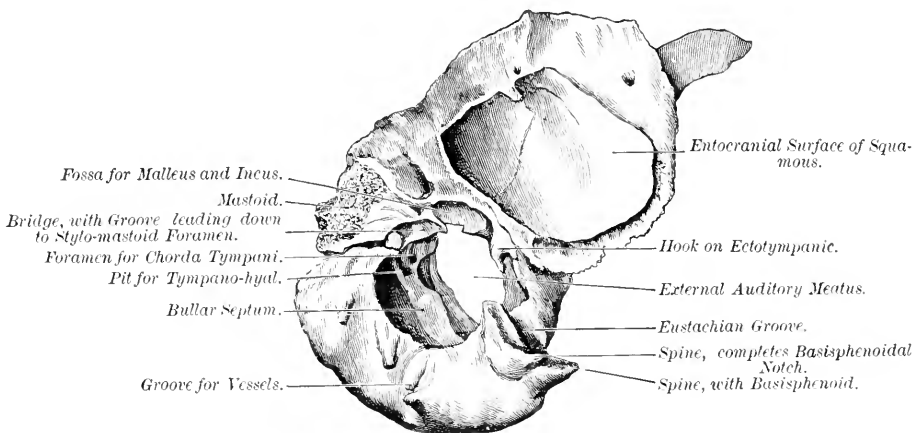


TRANSVERSE VERTICAL SECTION OF SKULL THROUGH EXTERNAL AUDITORY MEATUS.

outside by the line separating the ectotympanic and entotympanic bones. The septum is directed upward and inward. At the upper margin it is turned sharply outward, thus forming a flattened upper surface, directed from in front backward, outward, and downward. This surface is wide in front, where it rests on the promontory of the petrous, and narrow and emarginate behind, where it forms the lower

margin of the opening of communication between the two chambers. A cleft is left between the promontory and the septum through which vessels and nerves from the inner side of the bulla reach the tympanum. The septum is concave without and convex within, thus encroaching on the inner chamber. Its upper free margin is covered in front by the inner part of the front of the entotympanic part of the superior surface of the bulla. It curves downward and outward into the posterior edge of the anterior part of the ectotympanic superior surface and forms part of the floor of the Eustachian canal. It

FIG. 146.



LEFT TEMPORAL BONE. INNER SURFACE. PETROUS PORTION REMOVED.

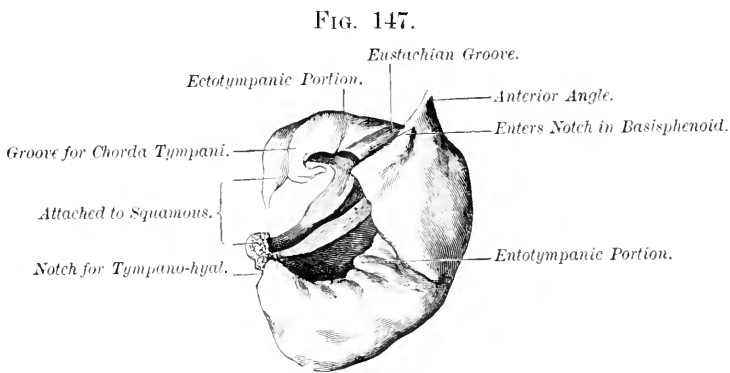
ends behind by bifurcating (Fig. 146); the outer horn joins the inner rim of the external auditory meatus, and the inner horn curves inward and upward to become continuous with the posterior part of the free outer margin of the superior surface of the bulla. The small angle included between these horns forms the roof of the pit for the tympano-hyal, and is sometimes perforated at the bottom. On the outer horn, just above this angle is attached a small bony and cartilaginous rod which stretches across the chamber and sometimes touches the promontory between the fenestra rotunda and the fenestra ovalis. This rod supports the chorda tympani nerve which enters the bulla through a foramen just inside its base. The outer opening of the foramen is seen in the front part of the terminal portion of the aquæductus Fallopii.

The outer chamber of the bulla forms the floor of the tympanum, or middle ear. It is crescent-shaped, wider in front than it is behind.

The internal surface is thickened in a narrow band round the inner rim of the external auditory meatus. To the sharp, everted, lower edge of this rim the drum of the ear, the *membrana tympani*, is attached.

The inner chamber of the bulla is much larger than the outer chamber, and extends further back. It is larger behind than in front. A transverse section made perpendicular to the septum is crescentic.

The **superior surface** (Fig. 147) of the bulla is formed by the turning of the upper edge of the external surface inward in all directions toward the centre of the bulla. The parts belonging to the



SUPERIOR SURFACE OF LEFT AUDITORY BULLA.

entotympanic and ectotympanic are separated behind by a notch forming part of the pit for the tympano-hyal, and in front by a groove, the lower wall of the Eustachian canal.

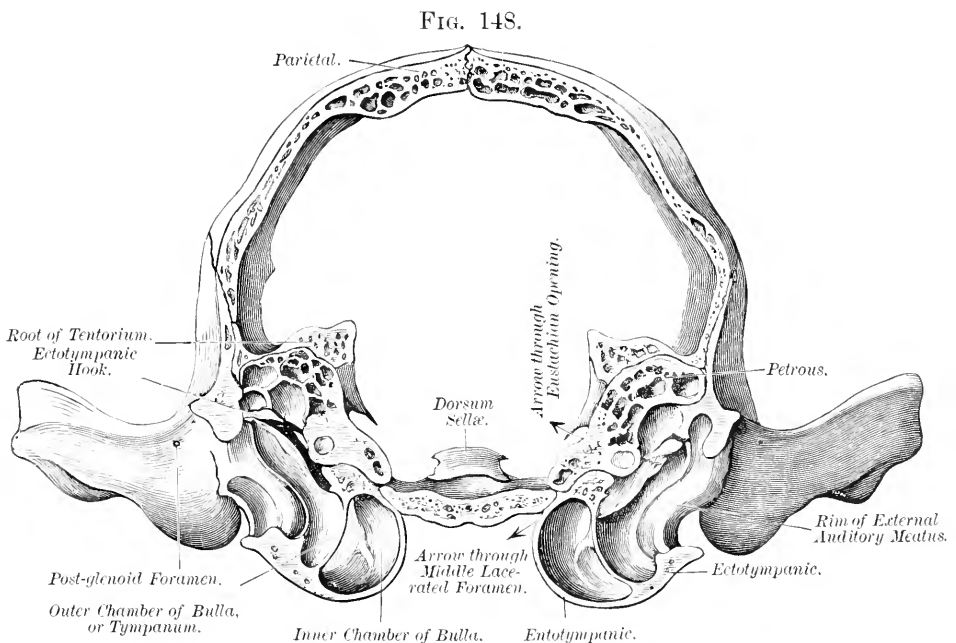
The inner, entotympanic portion is crescentic, the emargination facing outward and forward. In general, this surface is convex transversely and is wide and flat in front, and narrow and more convex behind. The anterior border of the entotympanic portion of the superior surface of the bulla is the sharp edge of the Eustachian groove. It is straight and directed obliquely forward and inward, and the inner angle is produced into a sharp process. The emarginate outer border is sharp and notched near the middle. The arcuate inner border is parallel with the outer border behind, but straight in front. It is not clearly defined from the general external surface of the bulla. On the flat part in front, just behind the anterior border and parallel with it, is an elevated ridge which is prolonged inward and forward to a point. The inner surface of this ridge is fastened to the outer surface

of the ridge on the outer edge of the basisphenoid. The point wherein it ends enters the large notch on the outer part of the posterior border of the basisphenoid. The outer surface of the ridge is fastened to the outer bevelled edge of the same notch. Anterior and external to the ridge the anterior border of the superior surface of the entotympanic is crossed obliquely by a groove for the small internal carotid artery, which enters the cranial cavity through a rudimentary middle lacerated foramen formed between the sphenoidal notch, the entotympanic, and the apex of the petrous. The sharp process at the anterior angle of the entotympanic part of the superior surface is also fastened to the basisphenoid in front of the notch. The upper surface of the ridge is applied to the petrous, as is all the rest of the entotympanic portion. At about the middle of the entotympanic part of the superior surface are several transverse grooves, sometimes deepened into canals, for the transmission of nerves and vessels from the base of the cranium.

The ectotympanic part of this surface is much smaller and is not continuous, inasmuch as the posterior third is lacking, except a small round area which is attached to the posterior part of the under surface of the squamous of the temporal. The gap thus left is filled by the part of the rim of the auditory meatus on the squamous. The anterior two-thirds are crescentic, the concavity of the crescent pointing inward and backward. It is narrowest on the inside and widest near the middle. It is divided into two parts by an alteration in the direction of its plane which takes place along a middle longitudinal line. The inner half is flat, and its plane faces slightly forward as well as downward, nearly parallel with that of the entotympanic surface, but it lies somewhat higher. This part is seen to be the groove which forms the floor of the Eustachian tube, and which has been described as separating the ectotympanic from the entotympanic portion. It is, in fact, the upper inclined edge of the septum of the bulla. The part of the ectotympanic surface lying outside of this groove is kidney-shaped; the long axis is directed obliquely inward and forward. Its inner, sharper edge is emarginate; near its posterior termination is a hook, which is directed forward, and behind which is a notch leading to a groove for the chorda tympani nerve, crossing the surface obliquely but almost parallel to the long axis of the skull. The rounded posterior end is turned sharply upward and inward, and presents a smaller, rough, triangular surface, facing upward, backward, and outward, which

is firmly attached to an area on the under surface of the squamous. The outer arcuate border is rounded. The plane of this surface faces outward, forward, and upward. It is applied to the lower surface of the alisphenoid and to the squamous of the temporal, without touching at all points; it thus forms the lower wall of the Glaserian fissure; the deep groove for the chorda tympani becomes closed to form the canal of Huguier.

**The Tympanum.**—The outer chamber of the auditory bulla, lying between the base of the skull and the ectotympanic, is known as the tympanum, or middle ear (Figs. 145, 148). It is a lens-shaped cavity;



THE SKULL. TRANSVERSE SECTION THROUGH EXTERNAL AUDITORY MEATUS, SEEN FROM BEHIND.

when seen from the side its outline is almost circular, but seen from above or below it appears as a long oval. The vertical and longitudinal diameters are, therefore, almost equal, and are twice as great as the transverse diameter.

The cavity does not lie parallel, however, to the median longitudinal vertical plane of the skull, but is so placed that its antero-posterior diameter passes from in front backward and outward and its vertical axis is directed from above downward and inward. The cavity is not perfectly regular; its walls are marked by the eminences and depressions on the investing bones. It is widest below the middle.

In the macerated skull it opens widely on the side of the head by the large external auditory meatus, and communicates behind with the inner chamber of the bulla through an opening above the common septum.

It is pierced in front, close to the base of the skull, by three canals: the inner and larger is the Eustachian opening; the middle canal, more or less confluent with the inner, is the Glaserian fissure, in a part of which is formed the small canal of Huguier.

In the temporal bone, before the removal of the soft parts, the external auditory meatus is closed by the drum of the ear or tympanic membrane, and the Eustachian canal lodges the partly cartilaginous Eustachian tube, which, by opening in front on the back wall of the pharynx, puts the middle ear in communication with the throat. The Glaserian fissure admits to the tympanum the tympanic branch of the internal maxillary artery, and the canal of Huguier gives exit to the chorda tympani nerve.

The middle ear contains the ear-ossicles, three minute bones which form a chain across its posterior and upper part; two small muscles which move the ossicles; and nerves and blood-vessels. The greater part of the cavity, however, is empty.

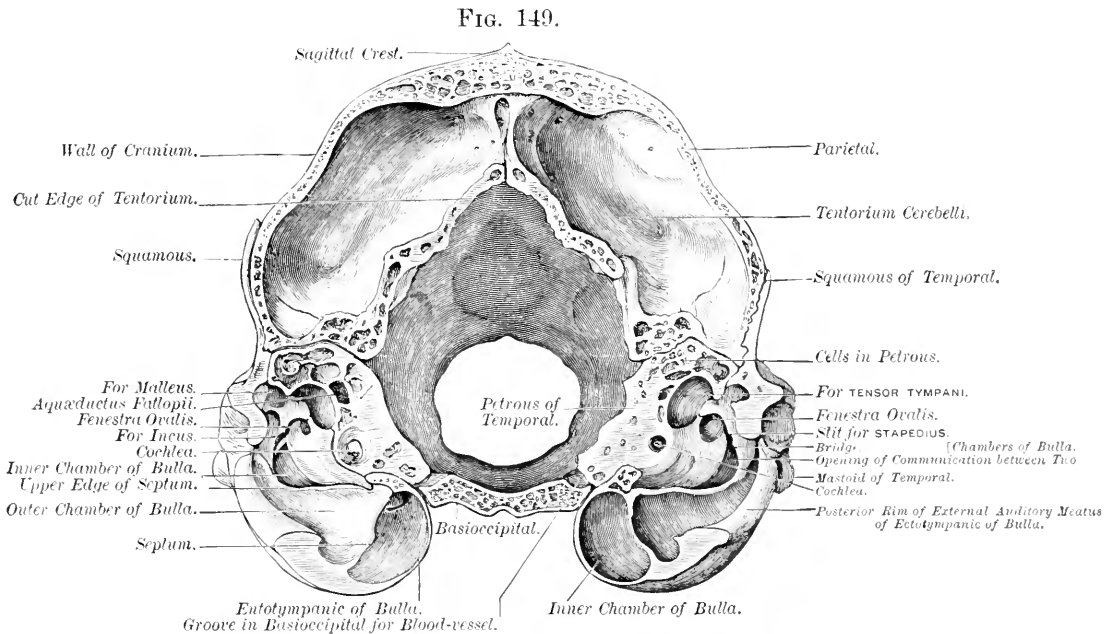
The **roof** of the tympanum is wide in front and narrow behind. It is formed principally by the inferior surface of the petrous of the temporal, but a strip of the inferior surface of the squamous runs along the outer edge, and at the anterior end are seen on the outside the ventral surface of the introverted upper edge of the ectotympanic, and on the inside a triangular area of the inferior surface of the alisphenoid continued forward, dorsal to the inner part of the edge of the ectotympanic, as the roof of the Eustachian opening (Fig. 137).

The middle of the roof is occupied by the large oval fossa for the tensor tympani muscle. Behind and at the outer side of this fossa is a second fossa, which lodges the heads of the two larger of the ear-ossicles, the malleus and the incus. On the median side of this latter fossa is the anterior end of a bridge of bone coming from the squamous and joining the petrous. On the inside of this bridge is the slit for the stapedius muscle. In front of the large fossa for the tensor tympani is the prominent, flattened, hooked process of the anterior edge of the ectotympanic. At the base of the hook on the outside are a groove and pit in which the long process of the malleus is attached by



ligament; dorsal to the hook itself is the canal of Huguier for the chorda tympani nerve. Straight across from these features, at the inner end of the suture between the petrous and the sphenoid, and at the anterior end of the septum of the bulla, is an opening into the cranial cavity for the Vidian nerve.

The **inner wall** of the tympanum faces outward, downward, and forward. Its upper part is contributed by the petrous and the upper part of the bullar septum. The septal part of the wall is smooth and concave, but the petrous portion shows the features peculiar to its surface, the promontory in front and the fenestra ovalis above and behind.

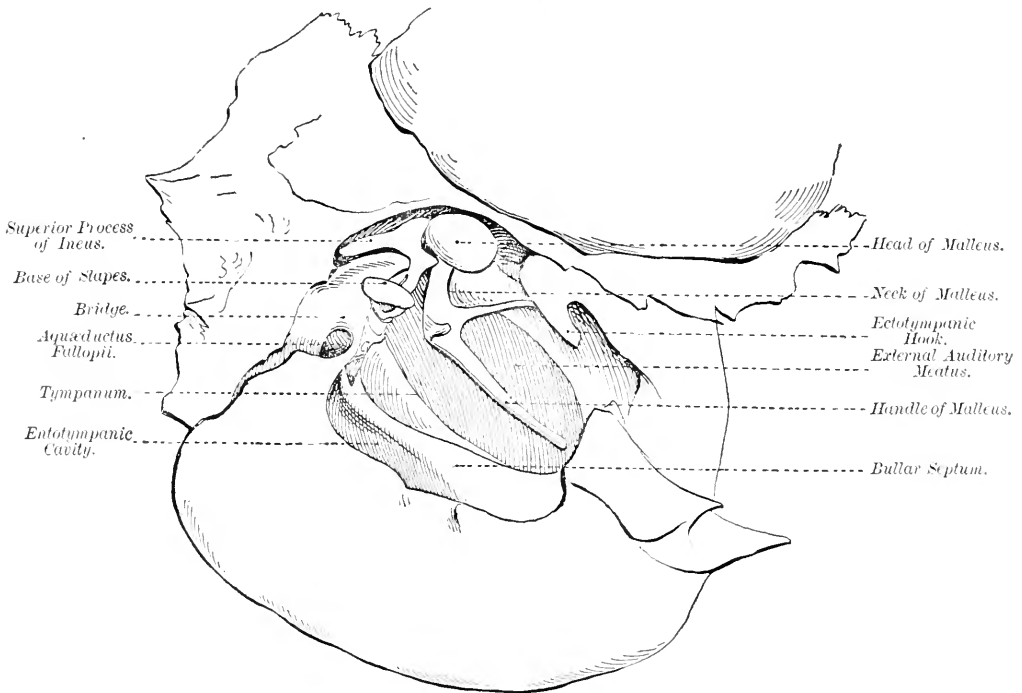


TRANSVERSE VERTICAL SECTION OF SKULL THROUGH EXTERNAL AUDITORY MEATUS.

The **outer wall** of the tympanum faces backward and inward and somewhat upward; it is little more than a ring surrounding the external auditory meatus. It is formed by the ectotympanic, except the upper part, which is derived from the squamous. It presents a circular elevated strip forming the margin of the auditory meatus. This strip is wider in front and quite disappears behind and above. Around this margin, below and in front, the wall is concave; it ends at the posterior wall at a point where the septum joins the edge of the auditory meatus. Above this point is the outer part of the fossa for the incus and malleus.

The anterior wall (Fig. 148) faces backward and to a slight degree outward, and is strongly concave from above downward and from side to side. It passes below into the lower wall, or, rather, into the groove formed by the meeting of the outer and the inner wall. It forms a decided angle with the upper wall. The anterior wall is an oblong strip passing from above downward and inward; above and within are seen the slit-like opening of the Eustachian canal and the Glaserian fissure, and on the outer side the ectotympanic hook and the opening of the canal of Huguier. On the inner wall of the Eustachian canal is the minute foramen for the carotid artery.

FIG. 150.



LEFT EAR OSSICLES IN POSITION. (PETROUS REMOVED.) SUPERIOR MEDIAL ASPECT.

(Enlarged Four Times.)

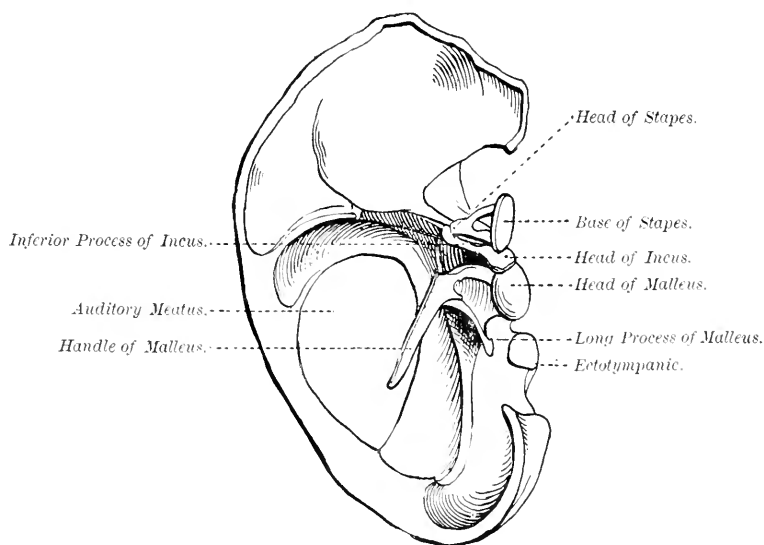
The posterior wall of the tympanum (Fig. 149) has the same general outline as the anterior wall. To the outer side of the middle is seen the crescentic opening into the inner chamber over the septum of the bulla. Below this opening the edge of the septum passes upward and outward to join the rim of the auditory meatus. A little within this point of junction is the opening for the chorda tympani. Above this opening is a fossa bounded on the outside by the squamous

and on the inside by the bridge of bone extending to the petrous. On the inside of the bridge is the slit for the stapedius tendon, and then comes the petrous, forming the inner part of the posterior wall. The foramen above, just median to the interbullar opening, is the fenestra ovalis.

#### THE EAR-OSSICLES.

The ear-ossicles are three very small bones, known as the **malleus**, the **incus**, and the **stapes**, which form a chain across the upper part of the tympanum, from the tympanic membrane, or drum of the ear, which closes the external auditory meatus, to the membranous covering of the fenestra ovalis of the petrous. The malleus is the anterior ossicle (Fig. 150); its long handle projects downward, forward, and inward on the inner surface of the tympanic membrane; its rounded head is lodged

FIG. 151.

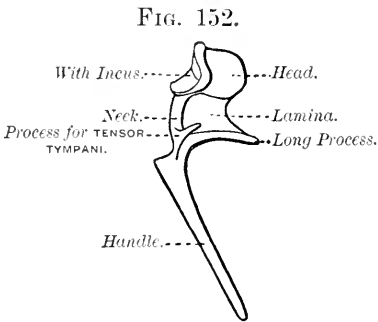


LEFT EAR OSSICLES IN POSITION. INFERIOR MEDIAL ASPECT.  
(Petrous and Lower Walls of Bulla removed. Enlarged Four Times.)

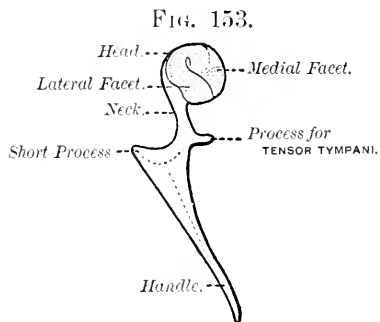
in a fossa on the inferior surface of the squamous. The incus lies almost directly behind the malleus, with the upper part of which it articulates. The stapes is directed almost at right angles to the other ossicles (Fig. 151), crossing the tympanum from without inward and upward. Its narrow outer end is attached to the incus, and its broad inner end, which is on a higher level, fits into the rim of the fenestra ovalis. The vibrations of the tympanic membrane move the long lever of the malleus and rock the heads of the malleus and incus on a longitudinal axis, and thereby push the broad end of the stapes slightly

in and out of the fenestra ovalis. In this way the vibrations of sound are transmitted from the exterior to the fluid filling the internal ear and are appreciated by the end filaments of the auditory nerve.

The **Malleus**<sup>1</sup> is the largest of the three ossicles, and measures about eight millimetres in length and three millimetres in width. It is composed of an upper broad portion (Fig. 152), and a lower slender portion, called the **handle** or **manubrium**, which is longer than the upper portion and is bent forward from it at an angle of about one hundred degrees.

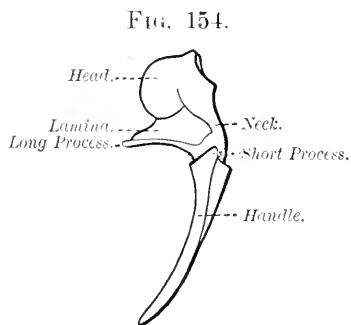


LEFT MALLEUS. MEDIAL ASPECT.  
(Enlarged Five Times.)



LEFT MALLEUS. POSTERIOR ASPECT.  
(Enlarged Five Times.)

The upper portion is surmounted by an ovoid **head**, which bears on its posterior aspect (Fig. 153) a deep **articular cavity** for the head of the incus. This cavity encroaches slightly upon the inner aspect of the bone; it is divided into **two facets** by a groove which begins at



LEFT MALLEUS. LATERAL ASPECT.  
(Enlarged Five Times.)

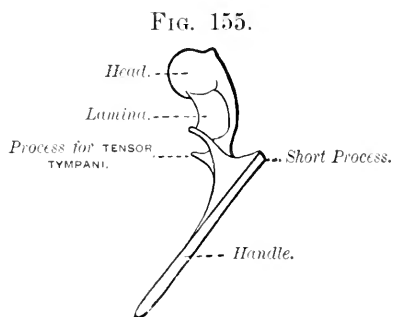
the inner lower border and ends in a circular depression before reaching the upper outer border. The facets slope toward the groove, and each is crossed by a convex ridge, thus producing four articulating surfaces. The upper surfaces of the outer and inner facets together form an almost circular fossa; the lower surface of the inner facet is flat or gently concave in both directions; the lower surface of the outer facet is convex in both directions.

The head is joined to the handle by a long slender **neck** (Fig. 154), which is cylindrical and describes a sinuous curve outward, in-

<sup>1</sup> A hammer.

ward, and outward again. Where the neck joins the handle on the anterior side a slender rod, known as the **long process**, projects forward and slightly upward. The upper margin of this process is connected with the anterior edge of the neck and the lower part of the head by means of a thin **lamina** of bone, often broken in removing the ossicles from the tympanum. The pointed end of the long process fits into a pit (Fig. 151) in the under surface of the ectotympanic, to which surface the thin free margin of the lamina also is attached by membrane. Where the neck, the handle, and the long process meet on the inner side of the bone (Fig. 152) is the point of origin of a **small process** which curves forward and upward and affords attachment for the tendon of the tensor tympani muscle.

The **handle** of the malleus is almost straight, or gently concave forward, and turned slightly outward at the lower end. In its upper part it is prismatic, presenting outer, anterior, and posterior surfaces; in its lower part it is compressed from within outward, and hence presents only inner and outer surfaces. The **outer surface** (Fig. 154) is long, narrow, and flat; it is fastened to the tympanic membrane. Its upper end projects higher than the other surfaces and forms an external heel which is known as the **short process**. The **anterior surface** (Fig. 155) is wide, excavated above and narrow below where it becomes continuous with the posterior surface. The **posterior surface** (Fig. 153) resembles the anterior surface, but is not excavated above; it is separated from the neck and from the process for the tensor tympani muscle by a wide, oblique groove.



LEFT MALLEUS. ANTERIOR ASPECT.  
(Enlarged Five Times.)

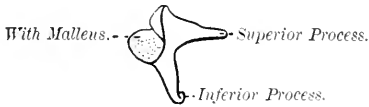
The **Incus**<sup>1</sup> (Fig. 156) is much smaller than the malleus, measuring but two millimetres in length and three millimetres in height. It has the shape of a tooth with two diverging fangs.

The anterior surface of the **head**, the surface which corresponds to the crown of a tooth, is occupied by a **cavity** for articulation with the head of the malleus. This cavity encroaches slightly on the outer aspect of the bone. Like the cavity on the head of the malleus, it is

<sup>1</sup> An anvil.

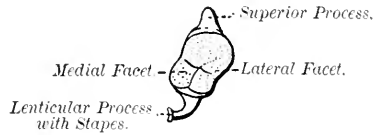
composed of two facets (Fig. 157), but the directions of their surfaces are, of course, reversed.

FIG. 156.



LEFT INCUS. LATERAL ASPECT.  
(Enlarged Five Times.)

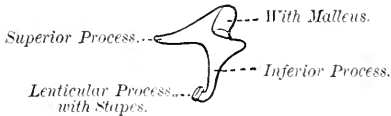
FIG. 157.



LEFT INCUS. ANTERIOR ASPECT.  
(Enlarged Five Times.)

Of the two processes of the incus, the **superior process** is the shorter and more conical. It is directed almost horizontally backward in the fossa formed between the squamous and the bridge (see p. 196), and its end is attached to the squamous by a ligament.

FIG. 158.

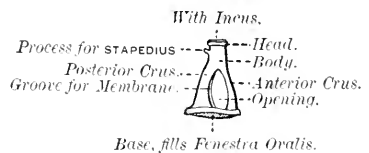


LEFT INCUS. MEDIAL ASPECT.  
(Enlarged Five Times.)

The **inferior process** (Fig. 158) is longer, and projects downward, backward, and outward; its end is bent sharply inward and upward and terminates in a small **orbicular** or **lenticular tubercle** which articulates with the stapes. In early life this tubercle is a separate element in the chain of ear-ossicles.

The **Stapes**<sup>1</sup> (Fig. 159) is the smallest of the three ossicles: its greatest diameter measures but two millimetres. It has the exact shape of a stirrup, and consists of a small disk-like **head**, resting on a larger **body**, which becomes gradually flattened from above downward until its cross-section becomes oval. On its posterior aspect is a small **tubercle** for the attachment of the stapedius muscle. The body splits into two **crura**<sup>2</sup> which surround an oval opening, filled in the recent state by a membrane attached in a groove. The **posterior crus** is shorter and stouter than the **anterior crus**. The **base** of the stapes is a thin oval plate, the lower edge of which is straighter than the upper edge. The outer side is joined at each end to the inner end of one of the crura in such manner as to

FIG. 159.



LEFT STAPES. INFERIOR ASPECT.  
(Enlarged Five Times.)

<sup>1</sup> A stirrup.

<sup>2</sup> Thighs; singular *crus*, a thigh.

leave free a narrow space along the margin. The inner side of the base is convex transversely, and is applied to the membrane in the fenestra ovalis.

The stapes forms with the incus an acute angle, sloping from the head inward, upward, and backward. The long axis of the base is about parallel with the zygomatic arch of the skull.

#### THE BONY LABYRINTH.

The petrous portion of the temporal bone conceals in its interior the internal ear or membranous labyrinth, a system of small sacs and tubes filled with fluid and bearing on their delicate walls groups of sensory organs richly supplied with branches of the auditory nerve. The cavities and canals of the petrous, which contain the internal ear, constitute the **bony labyrinth**; they are moulded so closely upon the membranous labyrinth that they conform closely to it in size and in shape. In young skulls the bony walls of the labyrinth are distinct from the cancellous tissue of the petrous, but as this becomes converted into compact tissue the outline gradually is lost.

To understand the structure of the labyrinth it is necessary to study it in a number of specimens and by three methods: (1) by making casts of the interior in fusible metal,<sup>1</sup> thus converting the cavities into solid bodies in order to show their shape and relative size and position; (2) by breaking away certain parts of the petrous and looking into the cavities in order to examine the features of their walls and the relation of their parts to the exterior of the bone; and (3) by cutting sections in various directions in order to establish the position of the parts with reference to the planes of the petrous and of the entire skull.

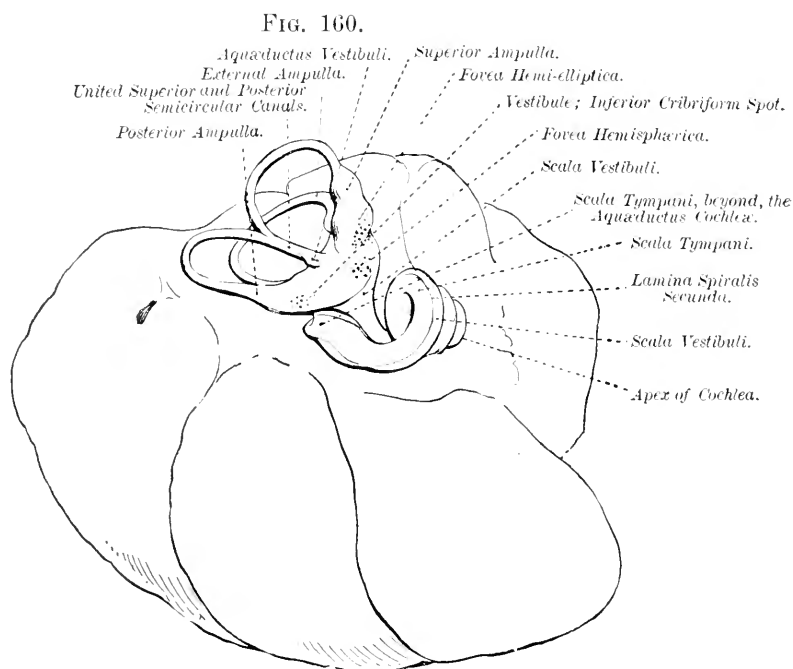
The metal cast (Fig. 160) shows that the bony labyrinth comprises (1) a posterior part, consisting of the semicircular canals; (2) a small middle cavity, the vestibule; and (3) a large anterior spiral canal, the cochlea.

The **semicircular canals** are three fine passages which traverse the posterior part of the petrous in horseshoe curves and open through their ends into the vestibule. From their general direction in the skull they are known as the superior, the posterior, and the external semicircular canal. Each canal lies, approximately, in one plane, and

<sup>1</sup> Bismuth, five parts; lead, three parts; tin, two parts.

the planes of the three intersect one another nearly in right angles, but do not correspond with the planes of the skull, nor even with the planes of the petrous.

The plane of the superior canal is frequently said to be transverse and vertical; it slopes, however, from the vestibule on the outside, inward and backward, and from above, downward and inward. The plane of the posterior canal is usually described as longitudinal and



METAL CAST OF LEFT BONY LABYRINTH AND AUDITORY BULLA.  
MEDIAL ASPECT. (Enlarged Four Times.)

vertical; it is, however, inclined from the vestibule in front, backward and outward, and from above, downward and outward. The plane of the external canal is often described as horizontal; it is, however, directed from in front, backward and outward, and from within, outward and upward.

One end of each canal enlarges as it enters the vestibule to form a flask-shaped *ampulla*.<sup>1</sup> The ampullæ of the superior and external canals are on their upper ends, the ampulla of the posterior canal is on its lower end. The lower non-ampullar end of the superior canal unites with the upper non-ampullar end of the posterior canal to form a single passage which opens into the vestibule between the external

<sup>1</sup> A wine-jar.



and superior ampullæ. The lower non-ampullar end of the external canal enters the vestibule so close to the ampulla of the posterior canal that the two appear to have a common opening. The three canals therefore communicate with the vestibule really by five openings, though apparently by only four.

The *aquæductus vestibuli* is a fine canal which begins at the posterior wall of the vestibule, immediately within and in front of the opening of the united non-ampullar ends of the superior and posterior semicircular canals, with which it runs parallel; it then diverges downward and inward and opens in the cleft at the posterior margin of the posterior surface of the petrous.

The *vestibule* is an irregular cavity, higher than it is wide or long, which in the dried bone communicates in front laterally with the tympanum by the fenestra ovalis and below with the cochlea; it communicates by five openings with the semicircular canals, and, sometimes, by the *aquæductus vestibuli* with the cranial cavity. The position of the vestibule within the petrous is indicated, externally, on the posterior surface by the posterior wall of the internal auditory meatus and the narrow surface between the meatus and the appendicular fossa. It is indicated on the inferior surface by the fenestra ovalis and the region above and lateral to it; also by the posterior wall of the fossa for the tensor tympani muscle and by the swelling anterior to the fossa for the stapedius muscle.

The *cochlea*<sup>1</sup> is the largest part of the labyrinth. It lies in the lower part of the petrous, in front and to the inner side of the vestibule. Its inferior and outer walls produce the swelling on the inferior surface of the bone known as the promontory. It lies in part in front of the anterior wall of the internal auditory meatus.

The cochlea encloses a tubular cavity, which is large behind and small in front and is twisted like a snail's shell three times round a central bony axis or column, the *modiolus*.<sup>2</sup> The general direction of this axis is in a longitudinal vertical plane, from behind forward and slightly downward; it is, however, subject to variations. The tubular cavity of the cochlea is divided lengthwise by a bony partition, the *lamina spiralis*, one edge of which is attached to the modiolus along a spiral line; the other edge does not quite reach the cochlear wall. There are thus formed two spiral canals, termed *scalæ*,<sup>3</sup> which

<sup>1</sup> A snail.

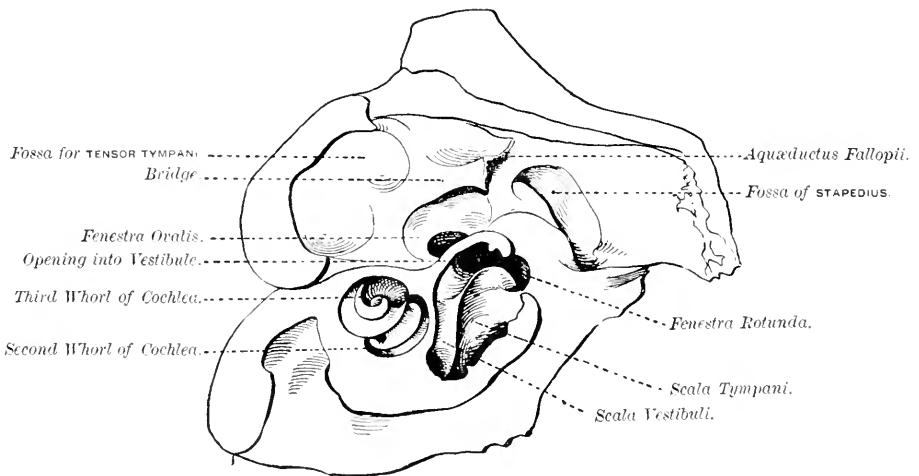
<sup>2</sup> The nave of a wheel.

<sup>3</sup> Ladders.

in the macerated bone are in communication along the free edge of the lamina spiralis, but in the recent state are shut off from each other by a membrane stretching from this free edge to a spiral ridge, the *lamina spiralis secunda*, on the wall of the cochlea. This ridge appears on the cast as a delicate spiral groove.

One of the *scalæ* opens behind and above into the vestibule; hence it is called the *scala vestibuli*. The other *scala* ends in an enlargement under the vestibule, which in the macerated skull opens freely into the tympanum through the fenestra rotunda; it is therefore called the *scala tympani*. It communicates also with the cranial cavity through the narrow *aquæductus cochleæ*.

FIG. 161.



LEFT PETROUS. INFERIOR ASPECT. (A PORTION OF INFERIOR SURFACE REMOVED.)

(Enlarged Four Times.)

The first spiral turn or whorl of the cochlea is indicated on the inferior surface of the petrous by the promontory proper; the other two whorls, which are much smaller, are contained in the swelling medial to the fossa for the tensor tympani muscle.

If the petrous be removed from the rest of the temporal bone, the student can see, by looking into the fenestra rotunda, the posterior part of the *scala tympani* in the first whorl, and just within the lateral part of the rim of the fenestra, between the edge of the lamina spiralis and the wall of the cavity, the slit which leads into the *scala vestibuli* and its posterior prolongation, the vestibule itself.

If the inferior wall of the promontory be carefully broken away, the ventral half of the first whorl of the cochlea will be then exposed

(Fig. 161). The posterior, larger cavity is the beginning of the scala tympani; its roof is formed of the modiolus and the lamina spiralis. In the medial posterior corner is the opening of the aquæductus cochleæ; at the lateral posterior part is the beginning of the slit between the lamina spiralis and the wall. At the anterior medial part the scala curves dorsally and laterally and disappears to complete the first turn. In front of the lamina spiralis, which in this part of the cochlea is wide and strongly curved, is the beginning of the scala vestibuli. It is narrower and not so deep; it lies in a lower plane than the scala tympani, and is directed almost transversely to the long axis of the skull. Its outer end turns upward and medially into the vestibule, just opposite the fenestra ovalis; its medial end turns upward and laterally and forward around the modiolus.

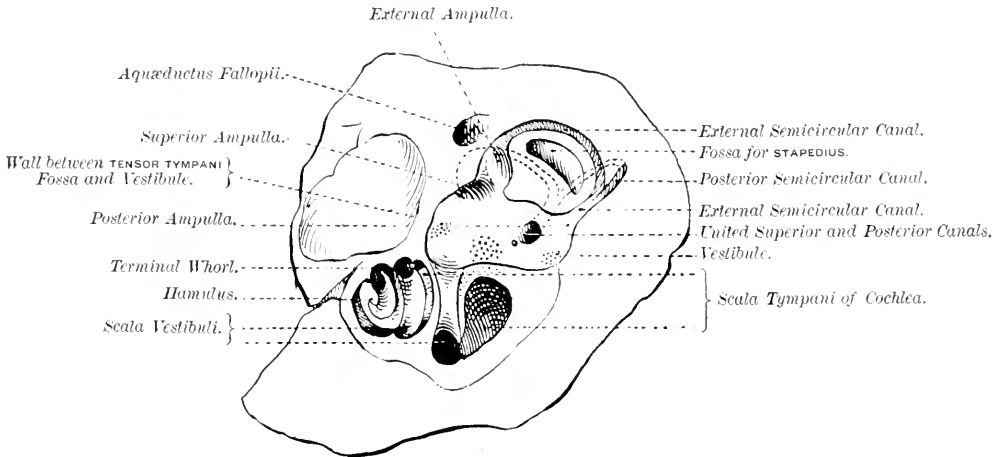
The anterior whorls of the cochlea should be opened by breaking away the ventral wall of the smaller swelling of the promontory. It will be observed that the scala tympani which began as the wider of the two scalæ has now become the narrower. On the cochlear wall opposite the free edge of the lamina spiralis is the lamina spiralis secunda. A second spiral line is sometimes present; it marks the attachment of another membrane. The spiral lamina ends in a hook-like edge in the anterior whorl.

The vestibule can be examined in the same specimen by removing its floor, the lamina spiralis, and the lateral portion of the modiolus in the first cochlear whorl (Fig. 162). The spiral area produced by breaking away the attached edge of the lamina is pierced by fine openings, which are the foramina of the posterior part of the spiral cribriform tract of the internal auditory meatus. Unless great care be observed, this rough area will be destroyed and a large opening made into the meatus.

The walls of the vestibule enclose an irregular ovoid cavity which is apparently bent forward so that the anterior wall is concave and the posterior wall convex from above downward. (Compare Fig. 163.) It is so inclined in the petrous that its upper part is nearer the side of the skull than the lower part, and its posterior part is nearer the middle line than the anterior part; its inner wall, therefore, in part overhangs the cavity, and the lower part of its outer wall is below the cavity; the upper part of the outer wall is pierced by the fenestra ovalis. The posterior wall is formed by the crescentic bony mass anterior and

medial to the fossa for the stapedius muscle. The anterior wall is not clearly defined; its inner part is behind the posterior wall of the internal auditory meatus; its outer part is the posterior wall of the tensor tympani fossa.

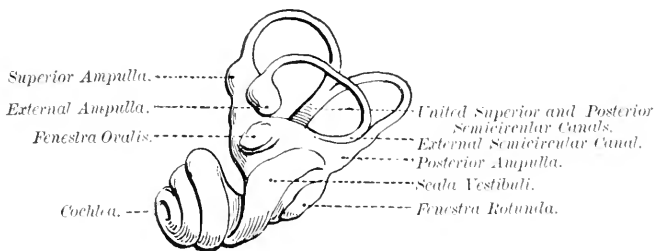
FIG. 162.



LEFT PETROUS. (INFERIOR SURFACE REMOVED.) (Enlarged Four Times.)

In the roof of the vestibule, at its posterior inner part, is the opening of the united non-ampullar ends of the superior and posterior semicircular canals; this opening is directed upward, backward, and inward. Just anterior and medial to it is the small inner opening of the aquæductus vestibuli. Behind and ventral to these openings is the ampulla on the lower end of the posterior semicircular canal; it is

FIG. 163.



METAL CAST OF THE LEFT BONY LABYRINTH. LATERAL ASPECT.

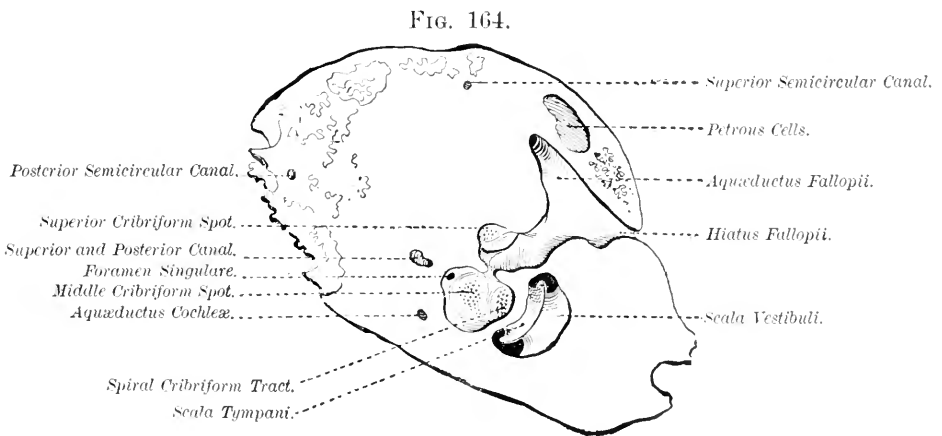
(Enlarged Four Times.)

directed outward, backward, and upward. At the anterior lateral part of the roof of the vestibule is the opening of the ampulla on the upper end of the superior semicircular canal; it is directed upward and outward. Behind and below this ampulla is another which leads

outward, backward, and upward into the external semicircular canal. This canal can be easily opened and its course traced behind the stapedius fossa to its lower end, namely, the groove on the convex lateral dorsal wall of the posterior ampulla.

Crossing the anterior wall of the vestibule from the upper rim of the fenestra ovalis, in front of the superior ampulla, is a porous pyramidal elevation, known as the **vestibular crest**. Above, anterior and lateral to the crest, is a depression, the **fovea hemi-elliptica**, which with the crest itself is pierced by the foramina from the superior cribriform spot of the auditory meatus; behind, below, and medial to the crest is a larger **fovea hemisphærica**, pierced by foramina from the middle cribriform spot. In the concave lower medial wall of the posterior ampulla is a group of fine openings from the posterior wall of the foramen singulare. All these openings transmit branches of the auditory nerve to the vestibule. In the metal cast they are indicated by patches of granulations (Fig. 160).

The relation of these features to the auditory meatus can be best seen by carefully grinding away a portion of the posterior surface (Fig. 164) of the petrous. The superior and posterior semicircular



LEFT PETROUS. MEDIAL ASPECT. (A PORTION OF POSTERIOR SURFACE REMOVED.)

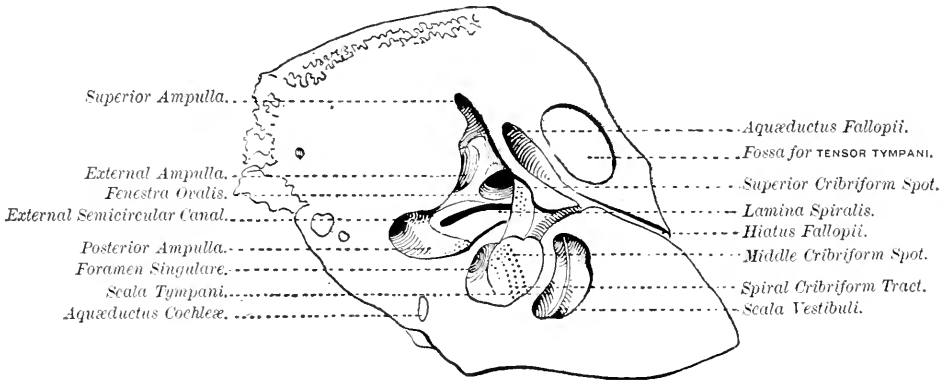
(Enlarged Four Times.)

canals will be first opened; then the aquæductus Fallopii and its anterior branch to the hiatus will be exposed; finally the terminal whorls of the cochlea become visible, and the aquæductus cochleæ is cut across.

If the grinding be carried still further (Fig. 165), the inner and

upper wall of the vestibule will be removed, exposing the outer wall with the fenestra ovalis; the slit leading down into the scala tympani; the floor formed of the lamina spiralis; the superior ampulla above; the external ampulla above and behind; the posterior ampulla below and

FIG. 165.



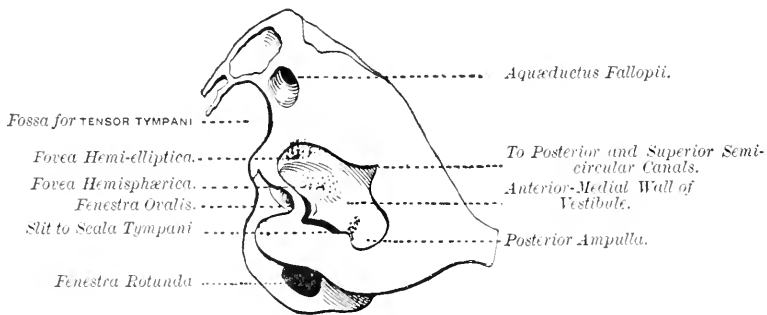
LEFT PETROUS. MEDIAL ASPECT. (POSTERIOR SURFACE REMOVED.)

(Enlarged Four Times.)

behind, with the non-ampullar end of the external canal grooving its wall. The common opening of the non-ampullar ends of the superior and posterior canals has been destroyed.

If the student have sufficient material, he should supplement these observations by others made on a series of sections through the internal ear.

FIG. 166.



TRANSVERSE SECTION OF LEFT PETROUS. POSTERIOR ASPECT.

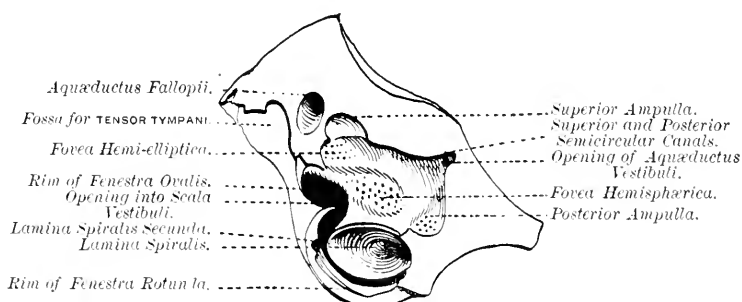
(Enlarged Four Times.)

The first section may be made across the petrous from above obliquely downward and backward, at the upper part cutting the posterior part of the tensor tympani fossa on the inferior surface and passing just posterior to the fenestra ovalis and the fenestra rotunda. The

posterior aspect of such a section (Fig. 166)—that is, the posterior surface of the anterior of the two pieces thereby produced—exhibits the following features:

In the superior part are the cells of the petrous forming the antrum of the tympanum; just under these is the oval section of the aquæductus Fallopii, to the outer side of which is the deep fossa for the tensor tympani muscle forming the upper part of the tympanum. Lower down is the large oval section of the vestibule; its upper outline is notched medially by a section of the beginning of the common canal of the non-ampullar ends of the superior and posterior semi-circular canals; the emargination in its upper outline is produced by the front of the superior ampulla; the deep emargination in its lower outline is part of the posterior ampulla. The upper arcuate

FIG. 167.



SECTION OF LEFT PETROUS TRANSVERSE TO LONG AXIS. POSTERIOR ASPECT. (Enlarged Four Times.)

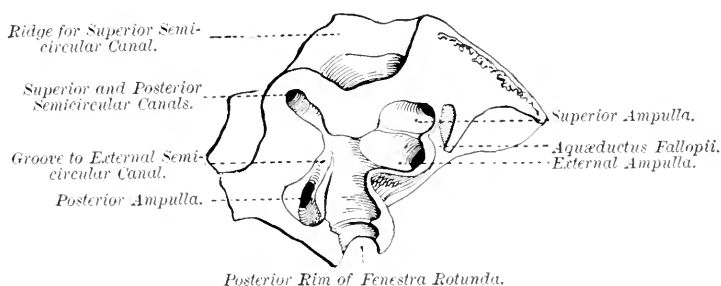
portion of the outer outline is formed by the rim of the fenestra ovalis, which can be seen on the outer aspect. A notch in the upper part of the rim is the section of a groove in which is fastened the membranous partition which closes the fenestra. The wall of the vestibule exposed to view comprises the anterior wall and parts of the upper and inner walls. Along the outer side is the opening into the scala tympani; at the upper part are the fovea hemi-elliptica and the vestibular crest; lower down is the fovea hemisphærica, and still lower, in the outer part of the posterior ampulla, are the fine pores from the foramen singulare. These areas are all in the part of the wall contributed by the posterior wall of the internal auditory meatus; the rest of the wall is formed by the posterior part of the modiolus and the lamina spiralis.

If the section be made transverse to the long axis of the petrous

just posterior to the tensor tympani fossa and dividing the fenestræ (Fig. 167), the anterior wall of the vestibule may be seen more clearly, and also the beginning of the lamina spiralis at the lower outer part; its line of attachment to the cribriform plate of the internal auditory meatus; and the manner in which it separates the vestibule from the scala tympani.

If the anterior aspect of this section (Fig. 168) be examined, the posterior part of the vestibule can be studied. Owing to the oblique

FIG. 168.



SECTION OF LEFT PETROUS TRANSVERSE TO LONG AXIS. ANTERIOR ASPECT. (Enlarged Three Times.)

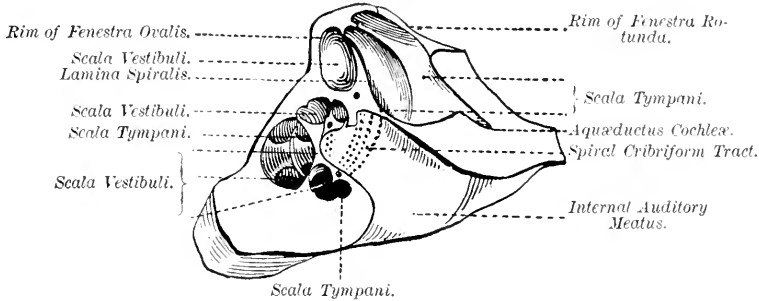
position of the petrous in the skull, the outer as well as the posterior wall is exposed. The upper inner part of the outline is emarginate because it is a section of the floor of the appendicular fossa, behind which is the swelling for the superior semicircular canal; the upper outer part is a section of the anterior surface. The lateral outline shows above a section of the tensor tympani fossa and the slit-like section of the aquæductus Fallopii. Below these features the outline is deeply incised by the fossa for the fenestra ovalis, and at the bottom of the section is the fenestra rotunda.

At the top of the vestibule is the divided superior ampulla; below it, the external ampulla. At the medial lower corner is the divided posterior ampulla, and, leading down into it, the groove for the non-ampullar end of the external canal. The long channel extending upward and inward from the upper outline of the vestibular wall is a section of the common canal for the non-ampullar ends of the superior and posterior semicircular canals. All these openings are defined by ridges; the actual posterior wall of the vestibule is confined to a small central area (Fig. 163). The fenestra rotunda appears to open into the vestibule, because the lamina spiralis has been destroyed.



The cochlea can be clearly shown by means of a section which divides the petrous obliquely, passing through the internal auditory meatus, the fenestra rotunda, and the superior border in front of the

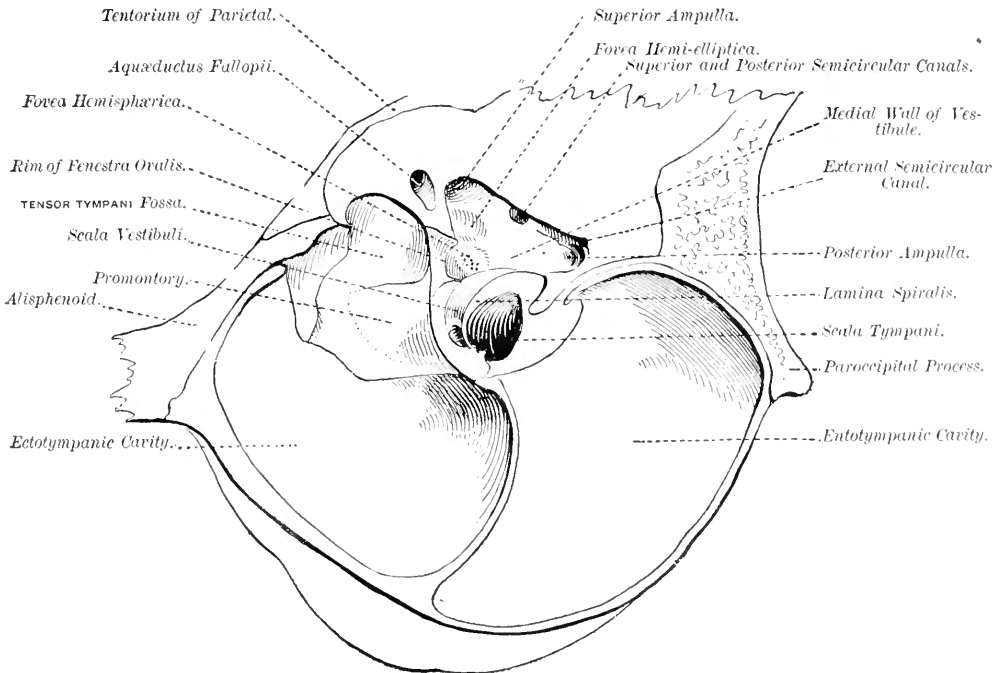
FIG. 169.



OBLIQUE SECTION THROUGH LEFT PETROUS, SHOWING COCHLEA.  
INFERIOR ASPECT. (Enlarged Four Times.)

hiatus Fallopii (Fig. 169). Such a section lies almost in the horizontal plane of the skull. The superior aspect shows no traces of the vestibule.

FIG. 170.

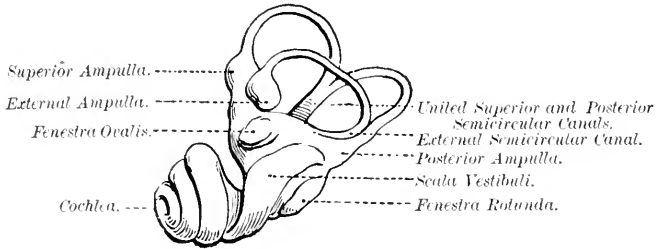


LONGITUDINAL VERTICAL SECTION THROUGH LEFT TEMPORAL. LATERAL ASPECT.  
(Enlarged Four Times.)

The exact relation of the parts of the bony labyrinth to the planes of the skull can be established only by sections made in those planes.

In Fig. 170 is represented the lateral aspect of that part of a longitudinal vertical section which passes through the temporal bone. It exhibits the true inner wall of the vestibule and part of the first whorl of the cochlea. It should be compared with the drawing of the cast of the labyrinth (Fig. 171).

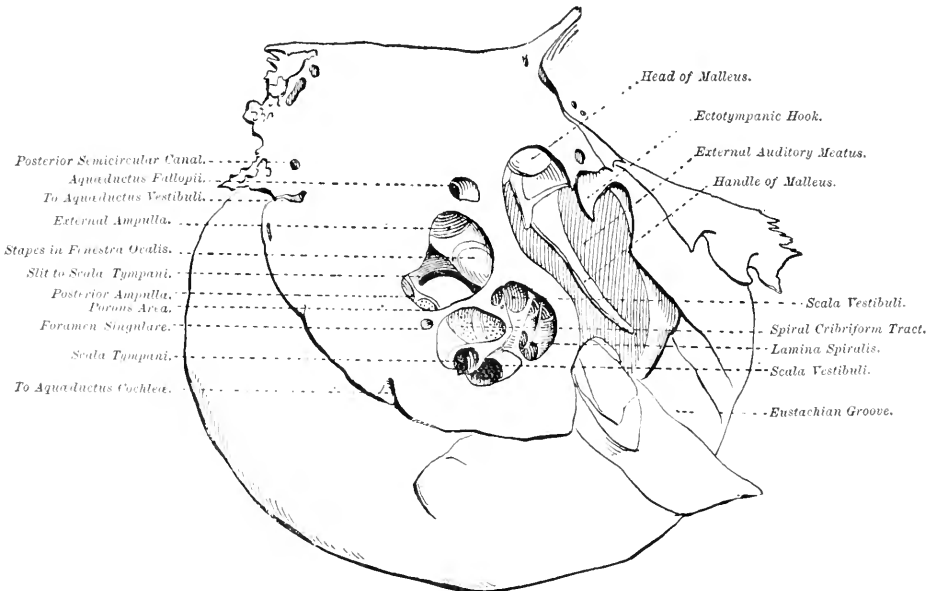
FIG. 171.



METAL CAST OF THE LEFT BONY LABYRINTH. LATERAL ASPECT.  
(Enlarged Four Times.)

The medial aspect of an oblique cranial section which passes through the superior and posterior borders of the petrous (Fig. 172)

FIG. 172.



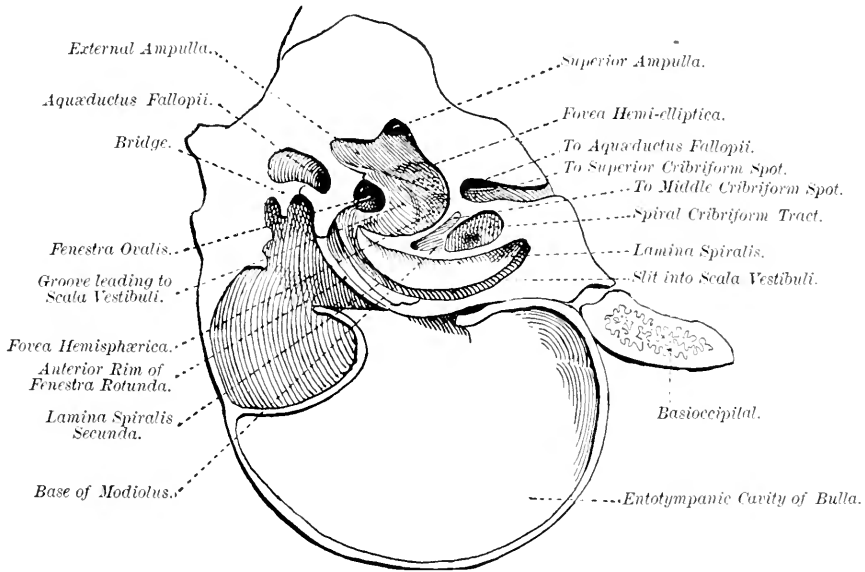
SECTION OF LEFT PETROUS THROUGH SUPERIOR AND POSTERIOR BORDERS. MEDIAL ASPECT. (Enlarged Four Times.)

is similar to the section illustrated in Fig. 165, but it passes lateral to the hiatus Fallopii and opens up more of the cochlea.

A transverse vertical cranial section through the posterior edge of

the internal auditory meatus (Fig. 173) differs from the section shown in Fig. 167 because it is oblique to the long axis of the petrous. It establishes the exact position of the vestibule in relation to the cochlea, the lamina spiralis, the cribriform spots of the internal auditory meatus, the aquæductus Fallopii, and the tympanum.

FIG. 173.



TRANSVERSE VERTICAL SECTION THROUGH LEFT TEMPORAL. POSTERIOR ASPECT.

(Enlarged Four Times.)

It will be observed that the inferior aspect of the transverse horizontal section (Fig. 174) is almost a complement of the section illustrated in Fig. 169. The position and direction of the cochlea, and the features on the roof of the vestibule, are well shown.

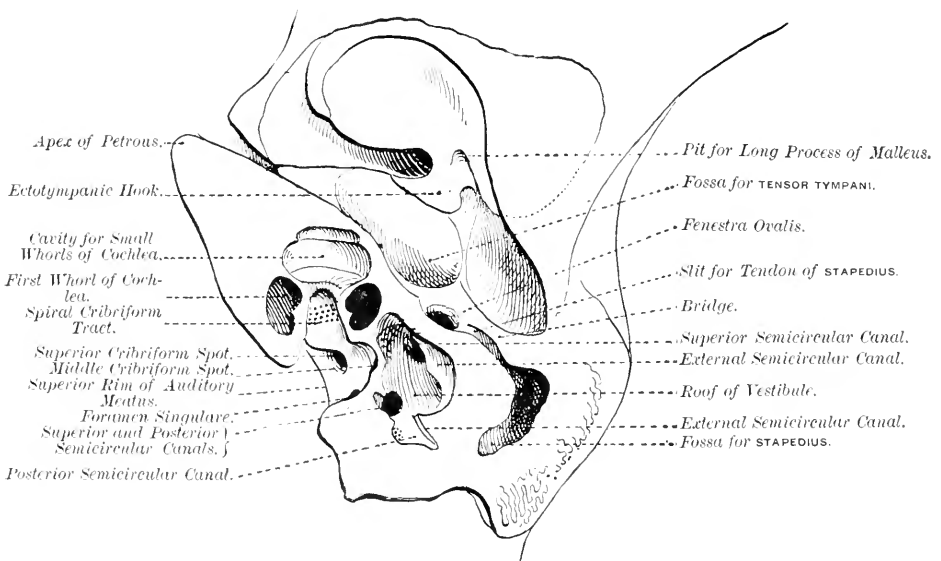
The **aquæductus Fallopii** begins at the internal auditory meatus and runs forward, outward, and slightly upward to a point anterior and medial to the fossa for the tensor tympani muscle (Fig. 165). Here it is joined by the branch from the hiatus Fallopii, and turns abruptly backward and outward and curves over the medial part of the tensor tympani fossa (Figs. 166, 167). It then leaves the petrous (Fig. 168), and, turning downward and outward, passes between the squamous bridge and the petrous (Fig. 173), then between the mastoid and the tympanic, and ends at the stylo-mastoid foramen. This terminal portion communicates with the jugular foramen by a canal between the bulla, the mastoid, and the occipital, for the trans-

mission of the auricular branch of the tenth cranial nerve; it communicates with the tympanum by a small chorda tympani opening in its anterior wall, and with the fossa for the stapedius muscle.

**Nomenclature.**—This bone is called the temporal bone, *os temporale*, *os temporis*, or *os temporum*, from *tempus*, time, because of its situation on the side of the head, where gray hairs usually first appear “to mark the flight of time.” It has also been known as *os parietale inferior*, *os lapidosum*, the stony bone, *os squamosum*, and *os eotaphicum*, from the Greek meaning the temple. The German word is *das Schläfenbein*; the French, *le temporal*.

The squamous portion is also known as the squamosal, *pars squamosa*, or the *squama*. In German it is called *die Schuppe*; in French, *l'écaille*, or *la portion écailleuse*.

FIG. 174.



TRANSVERSE LONGITUDINAL SECTION THROUGH LEFT TEMPORAL. INFERIOR ASPECT.

(Enlarged Four Times.)

The petrous portion is also known as the petrosal, *os petrosum*, *pars petrosa*; in German as *das Felsenbein*; in French as *le rocher*. The mass formed by the union of the petrous with the mastoid is termed the petro-mastoid, the petrosal, or, because it encloses the internal ear, the periotic.

The mastoid is also known as *pars mastoidea*, *die Warzenpartie*, *la portion mastoïdienne*.

The tympanic portion is also known as the tympanic plate and

os tympanicum; in French as *la partie ou caisse tympanique*; in German as *das Paukenbein* or *der Paukentheil*.

**Determination.**—If the temporal be held with the external auditory meatus uppermost and the thin border of the squamous away from the student, the zygomatic process will point to the side, right or left, to which the bone belongs.

**Articulation.**—The temporal articulates with the occipital, the parietal, the basisphenoid, the alisphenoid, the malar, and the mandible.

**Muscular Attachments.**—The principal muscles attached to the temporal are: the **temporal**, to the outer surface of the squamous; the **masseter**, to the zygomatic process; the **sterno-mastoid**, the **splenius**, the **trachelo-mastoid**, the **rectus capitis lateralis**, the **cleido-mastoid**, and the **stylo-glossus**, to the outer surface of the mastoid; the **stylo-hyoid**, to the posterior part of the bulla; the **stapedius**, the **tensor tympani**, the **levator palati**, and the **tensor palati**, to the inferior surface of the petrous.

**Ossification.**—The details of the development of the temporal bone have not yet been satisfactorily investigated. We know, however, that the various primary centres of ossification coalesce to form four elements which for some time remain entirely distinct. These are the squamous, the petro-mastoid, the ectotympanic, and the entotympanic. The malleus and incus are developed from the upper part of the primitive lower jaw, known as Meckel's cartilage. The stapes is developed from the cartilage surrounding the fenestra ovalis.

#### VARIATIONS IN THE TEMPORAL BONE.

##### VARIATIONS IN SIZE.

The measurements were taken on left temporals only, as follows:

The maximum length is the distance from the tip of the zygomatic process to the posterior end of the squamo-mastoid upward prolongation projected on ruled paper, the posterior root of the zygoma being horizontal.

The maximum height is the distance from the lowest point of the bulla to the highest projected point of the squamous, at right angles with the length measurement.

The squamous height indicates the distance from the lower edge of the postglenoid process to the highest projected point of the squamous.

The squamous length is the basal length of the squamous from the beginning of the anterior border to the posterior upper edge of the stylo-mastoid foramen.

The petro-squamous width is taken between the posterior root of the zygoma, at its concave part, and the superior border of the petrous just behind its most prominent middle part.

The mastoid length is the distance from the upper posterior edge of the stylo-mastoid foramen to the end of the squamo-mastoid upward prolongation.

The width of the auditory meatus is its longest oblique diameter from behind and above forward and downward.

The height of the auditory meatus is its shortest oblique diameter from above downward and backward, at right angles to the preceding diameter.

The bullar length is the distance from the anterior spine of the entotympanic to the posterior end where the mastoid and the par-occipital process meet.

The bullar width is taken transversely to the preceding, across the anterior part from the outer, upper, and widest part of the ectotympanic to the inner edge of the entotympanic.

The glenoid length is the distance from the inner edge of the inferior border of the squamous along the anterior border of the glenoid cavity to its outer prominent end.

The glenoid width is the shortest distance between the most prominent part of the lower edge of the postglenoid process and the sharp edge of the anterior border of the glenoid cavity.

## MEASUREMENTS OF THIRTY TEMPORAL BONES.

Maximum length . . . . .	55.5 55	54.5 54	53	52.5 52	52	51.5 51	50	49	48.5 48	48	48	47	47	46.5 46	46	46	46	45	45	44.5 44	43.5
Maximum height . . . . .	31.5 31	32.5 32	31.5 32.5 31.5 31	30	33	30.5 29	29	29	29	30	29	29	30	31	31	29	28.5 30	30	28.5 29	31	
Squamous height . . . . .	23.5 27	23	24	24	23	24	24	23	20.5 28	29	22	19	22	20	19	24	24.5 21.5 24	20	21.5 21	21.5 23	22
Squamous length . . . . .	17	18	19	18.5 19	18	18	17.5 16	18	17.5 16	18	18	17	18	16.5 17	17	19	18	18	15.5 17.5 18	17	
Petros-squamous width . . . . .	11	11	10.5 11	12	10	11	9	10	10	11	10.5 10	8	9.5 10	9	10.5 11	8	9	10	10	9	11
Mastoid length . . . . .	22	20.5 22	21	20	19	20	19	19.5 18	18	19	18	19	18.5 16	18	16	19	20	18	17	17	20.5 19
Meatus width . . . . .	8	8	8	7	8	7.5 8	8	7	8	7	8	8	8	7	8	8	8	7	8	8	7.5
Meatus height . . . . .	5	4	5.5 4.5 5	5	5	4.5 5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5
Bullar width . . . . .	17	16	17	18	18	15	15.5 17	17	16	16	15	16	15.5 17	16	17	16	17	16	16	16	15
Bullar length . . . . .	21.5 23	21	20.5 21	22	21.5 23	22.5 19	22.5 22	20	19.5 20	21	21.5 22.5 21.5 20	21	20	21	21	22	20	19.5 20	19	22	
Glenoid width . . . . .	5.5 7	6	5	5.5 5	6	6.5 6	5	6	5	5	6	5	6	5	5	4.5 5	5	5	5	5	6
Glenoid length . . . . .	16	16	15	15.5 15.5 15	15.5 15	17	16	15	13	13	15.5 14	16	15	13	15	14	15	14	14	13.5 12	14

## VARIATIONS IN FORM AND DEVELOPMENT.

Beyond slight fluctuations in the relative prominence of the parts, the temporal bone presents few noteworthy variations.

It is said that the **postglenoid foramen** is absent in the cat; an examination of one hundred temporals, taken at random from a large collection, showed, however, that it was present in all but three. It varies somewhat in position, and is often hidden by the edge of the auditory bulla. In twenty-nine specimens it was at the medial side of the postcondyloid process; in nine of these it was accompanied by a second foramen, which was sometimes very large, situated at a distance dorsally and laterally on the surface of the zygoma. Its usual position is behind the inner end of the root of the process. The postcondyloid foramen may be double; the two foramina are then close together side by side, or one is in front of the other (three specimens); in one specimen there were three foramina. A small accessory foramen is sometimes to be seen in the fossa for articulation with the ectotympanic part of the bulla.

In one specimen a well-marked foramen was observed in the posterior root of the zygoma where it joined the lambdoidal ridge. In two specimens a foramen entered the posterior part of the outer surface of the squamous, midway between the zygomatic root and the superior border; in another a small foramen pierced the same surface, near the superior anterior border.

In the **petrous** portion of the bone, the superior border may be elevated in its basal part into a crest overhanging a decided groove for the superior petrosal sinus, which curves downward and backward to the groove for the lateral sinus. In its apical part the border may be deeply excavated for the fifth cranial nerve.

In some specimens the appendicular fossa in the posterior surface is very shallow, in others it is as deep as the auditory meatus and pierced at the bottom by a small foramen. The swelling for the superior semicircular canal may be abnormally high or may be entirely absent. In some specimens the position of the posterior semicircular canal is clearly outlined by a longitudinal elevation. The shape of the internal auditory meatus varies from oblong to round; the division for the facial nerve may be as large as the division for the auditory nerve. In many specimens the groove for the inferior petrosal sinus along the inferior border, as well as the opening for the aquæductus cochleæ,



is upon the posterior surface. The opening of the aqueductus vestibuli varies in position and in size; in some specimens the canal is not pervious.

The anterior surface of the petrous may be exceedingly narrow. In a large proportion of specimens it is marked by a groove which runs parallel with the anterior border and not far from it.

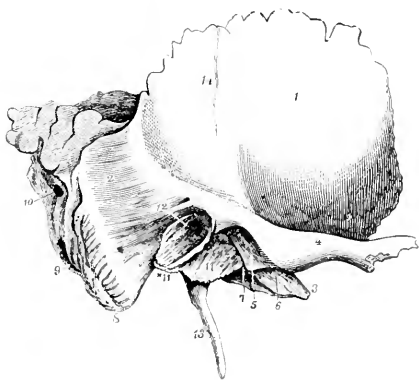
The inferior surface exhibits variations in the size and shape of the promontory. In some specimens the fenestra ovalis is almost as large as the fenestra rotunda; in others the fenestra rotunda is greatly enlarged; it is subject also to slight variations in the direction of its plane.

### HUMAN TEMPORAL BONE.

If the student has carefully followed the description of the temporal of the cat, the features of the corresponding human bone can be easily recognized; indeed, it is doubtful if the structure of the human temporal can be properly mastered and remembered without just such detailed work as has been given on a more generalized type, a type not less complicated, but showing clearly parts which in man are rudimentary or have suffered displacement in the antero-posterior compression of the base of the skull as a result of the relative overgrowth of the cranial vault.

The human temporal differs from a typical mammalian temporal in the following very obvious characters: The zygomatic process is relatively smaller; the mastoid portion of the bone is relatively larger (Fig. 175); the entotympanic part of the auditory bulla is absent, thus exposing on the base of the skull much of the inferior surface of the petrous (Fig. 177), while the ectotympanic part of the bulla enclosing the tympanum is a curved compressed tube, the external concave wall of which is separated from the glenoid cavity by the Glaserian fissure and is called the **tympanic plate**. The two proxi-

FIG. 175.



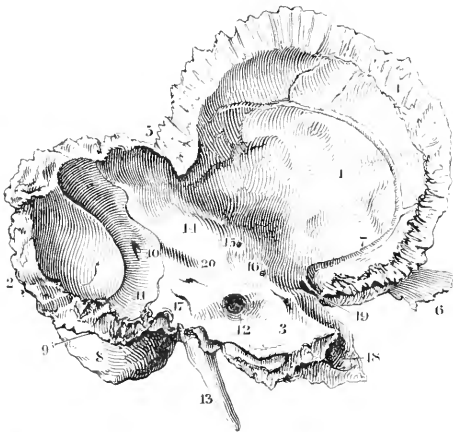
EXTERNAL VIEW OF THE TEMPORAL BONE, OF THE RIGHT SIDE.

1, squamous portion; 2, mastoid portion; 3, apex of the petrous portion; 4, zygomatic process; 5, glenoid fossa; 6, preglenoid tubercle; 7, glenoid fissure; 8, mastoid process; 9, back part of digastric fossa; 10, mastoid foramen; 11, tympanic plate forming the vaginal and auditory processes; 12, auditory meatus; 13, styloid process; 14, slight impression of the deep temporal artery.

mal elements of the hyoid, the tympano-hyal and the stylo-hyal, are coalesced and firmly fastened in a pit, thus forming the styloid process of the bone. The inferior surface of the petrous presents, just medial to the tympanic plate, a large circular foramen leading into a canal which bends forward and inward and, traversing the petrous, opens again at the apex. This is the canal through which the large internal carotid artery enters the cranial cavity (Fig. 179).

The remaining differences between the two temporals are principally differences in details. In the human bone the squamous is flatter, and its inner surface (Fig. 176) is more deeply marked by the

FIG. 176.



INTERNAL VIEW OF THE TEMPORAL BONE OF THE LEFT SIDE.

1, squamous portion; 2, posterior border of the mastoid portion articulating with the occipital bone; 3, petrous portion; 4, bevelled edge, which overlaps the lower edge of the parietal bone; 5, notch between the squamous and the mastoid portion, articulating with the posterior inferior angle of the parietal bone; 6, end of the zygomatic process; 7, groove for the great meningeal vessels; 8, mastoid process; 9, digastric fossa; 10, mastoid foramen opening into the groove, 11, for the lateral sinus; 12, internal auditory meatus; 13, styloid process; 14, prominence produced by the superior semicircular canal of the labyrinth; 15, tegmen; 16, position of hiatus of the facial canal; 17, cleft which communicates with the aqueductus vestibuli; 18, termination of the carotid canal; 19, Eustachian tube; 20, groove of the superior petrosal sinus.

cerebral convolutions and by grooves for the great meningeal vessels. A large part of the **glenoid cavity** (Fig. 177) is on the inferior surface of the squamous and a lesser part only on the zygomatic process; it is more nearly circular in outline and more deeply concave. It is bounded in front by the anterior root of the zygoma, or **articular eminence**, the outer end of which is sometimes called the **preglenoid tubercle**. A swelling at the outer posterior part of the cavity is called the **postglenoid tubercle**, and one at the medial end the **entoglenoid tubercle**. In front of the glenoid cavity is a smooth triangular area which forms part of the zygomatic fossa of the skull.

The **external auditory meatus** (Fig. 175) is a funnel-shaped canal; the everted irregular edge of the tympanic plate which forms the lower boundary of the meatus is called the **auditory process**.

The **mastoid process** is very large, and is separated behind from the rest of the mastoid portion by a deep groove, the **digastric fossa**, for the digastric muscle (Fig. 177). At the upper end of this fossa

is the **mastoid foramen**, which transmits a vein to the lateral sinus (Fig. 176), and behind the fossa is a smaller **furrow** for the occipital artery. The **inner surface** of the mastoid is deeply concave, and lodges the lateral sinus.

The **petrous** portion is relatively longer than the petrous in the cat; its apex reaches beyond the anterior margin of the glenoid cavity. It is a four-sided pyramid; the outer side is covered by the squamous and tympanic portions except at the apex.

The **posterior surface** (Fig. 176) is much narrower than the corresponding surface on the petrous of the cat; the superior border is marked externally by a groove for the superior petrosal sinus and internally depressed for the passage of the fifth cranial nerve. The **internal auditory meatus** is oblong, and the canal is directed outward and backward. The opening of the **aquæductus vestibuli** is in the posterior surface of the petrous, behind the auditory meatus. A rudimentary **appendicular (floccular) fossa** is sometimes present, below the groove for the petrosal sinus.

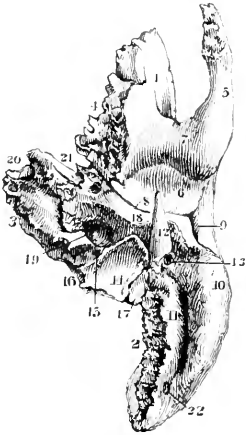
The **anterior surface** is wider than the posterior; its apex, which overhangs the carotid canal, is impressed by the Gasserian ganglion on the fifth nerve. The **hiatus Fallopii** is small, and lies to the inner side of a small opening for the lesser petrosal nerve. The position of the superior semicircular canal is indicated by a swelling, the **eminentia arcuata**, external to which is the thin part of the roof of the tympanum distinguished as the **tegmen tympani**. A petro-squamous suture often persists between this surface and the squamous.

The **inferior surface** (Fig. 177) presents at the outer posterior part the **stylo-mastoid foramen**, in front of which is the **styloid process** embraced on the outside by the produced lower margin of the tympanic plate known as the **vaginal process**. Lateral to the foramen is the tympano-mastoid suture, or **auricular fissure**, through which issues the auricular branch (Arnold's) of the tenth cranial nerve (Fig. 178). Medial to the foramen is a quadrate roughened area for articulation with the occipital bone. In front of this area is a deep transversely oval **jugular fossa**, which contains the beginning of the jugular vein. Its outer wall is pierced by a small **foramen**, the **auricular canaliculus**, for the auricular branch (Arnold's) of the tenth cranial nerve. Its inner margin is prolonged as the **jugular spine**.

The jugular fossa is separated from the posterior opening of the

carotid canal by a transverse crest which is pierced at its inner end by a foramen, the **tympanic canaliculus**, which transmits the tympanic branch (Jacobson's) of the ninth cranial nerve. Medial to this opening is the **petrous fossula**, in which is the opening of the **aquæductus cochleæ**.

FIG. 177.



INFERIOR VIEW OF THE LEFT TEMPORAL BONE.

1, squamous portion; 2, mastoid portion; 3, petrous portion; 4, border articulating with the great wing of the sphenoid bone; 5, zygomatic process; 6, glenoid fossa; 7, articular eminence; 8, Glaserian fissure; 9, auditory meatus; 10, mastoid process; 11, digastric fossa; 12, styloid process; 13, stylo-mastoid foramen; 14, jugular fossa; 15, pit which communicates with the aquæductus cochleæ; 16, position between which and the occipital bone the ninth, tenth, and eleventh cerebral nerves escape from the cavity of the cranium; 17, articular process; 18, vaginal process; 19, 20, entrance and exit of the carotid canal; 21, Eustachian tube; 22, mastoid foramen.

At this point the margin of the bone is grooved for the passage of the ninth, tenth, and eleventh cranial nerves. In front of the petrous fossula the inner margin of the surface exhibits a groove for the inferior petrosal sinus. Lateral to the groove is a rough space which articulates with the basilar plate of the occipital. The region of the surface near the apex under the carotid canal affords attachment to the pharynx. The posterior wall of the carotid canal is pierced by two small canals, the **carotico-tympanic canaliculi**, for tympanic nerves from the carotid plexus (Fig. 179).

In the notch, in front, between the petrous and the squamous is the anterior end of the Glaserian fissure. A small crest of the petrous appears between the squamous and the tympanic and bounds internally the canal of Huguier. On the medial side of this crest are the Eustachian opening below and the canal for the tensor tympani muscle above.

The human tympanum is usually divided into three parts: (*a*) the **atrium**,<sup>1</sup> the portion which is visible through the external auditory meatus; (*b*) the **attic**, the superior portion, which contains the heads of the malleus and incus; and (*c*) the

**antrum**,<sup>2</sup> an irregular space in the cancellous tissue of the petrous, behind the attic, with which it is in communication (Fig. 178). The atrium differs from the corresponding region in the tympanum of the cat in the following points: On the posterior wall, just behind the fenestra rotunda is a small **pyramid**, the apex of which is pierced by a foramen for the tendon of the stapedius muscle. The interior of the pyramid is hollow, and contains the muscle, which is supplied with

<sup>1</sup> The fore-court or hall.

<sup>2</sup> A cave.

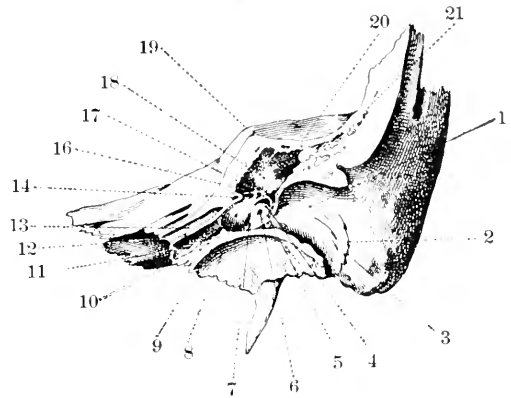
vessels and nerves through an opening behind into the aquæductus Fallopii. The pyramid corresponds to the bony bridge and the adjoining petrous wall in the tympanum of the cat. Close to the groove for the attachment of the tympanic membrane is the opening for the chorda tympani nerve. A fossa on the posterior wall behind and above the fenestra rotunda and beneath the pyramid is sometimes termed the **tympanic sinus**; in the cat it is represented by the lower part of the slit between the petrous and the bridge.

It is important to note that the fossa for the tensor tympani muscle is not a deep circular depression on the inferior surface of the petrous, but a long tube which extends forward

and inward above the Eustachian tube, from which it is separated by a scroll of bone, the **processus cochleariformis**, represented in the cat by the inverted superior part of the ectotympanic.

The tympanic canaliculus, beginning in the inferior surface of the petrous, opens at the bottom of the tympanum and is continued upward as a groove across the promontory (Fig. 179). It transmits the tympanic branch (Jacobson's) of the ninth cranial nerve, a branch of which runs upward through a canal in the petrous near

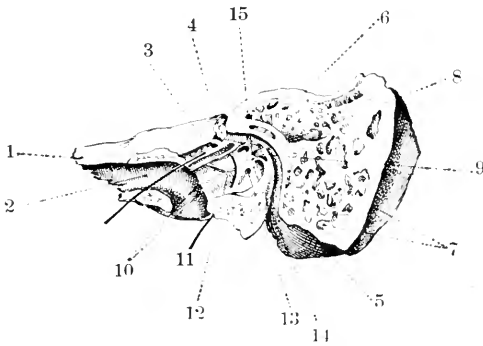
FIG. 178.



LONGITUDINAL SECTION OF TEMPORAL BONE, THROUGH THE TYMPANUM.

1, external auditory meatus; 2, auricular fissure; 3, opening of canal for Arnold's nerve; 4, tympanic sinus; 5, tympanic groove; 6, fenestra rotunda; 7, tympanic opening of the tympanic canaliculus; 8, promontory; 9, tympanic end of Eustachian canal; 10, small foramina; 11, Eustachian canal; 12, septum; 13, canal for the tensor tympani muscle; 14, processus cochleariformis; 16, fenestra ovalis; 17, swelling due to aquæductus Fallopii; 18, swelling due to external semicircular canal; 19, antrum of tympanum; 20, pyramid; 21, posterior sinus.

FIG. 179.



SECTION OF TEMPORAL BONE THROUGH TYMPANUM, CAROTID CANAL, AND AQUÆDUCTUS FALLOPII.

1, apex of the petrous; 2, carotid canal; 3, hiatus Fallopii; 4, 5, aquæductus Fallopii; 6, external semicircular canal; 7, mastoid cells; 8, pyramid; 9, sinus of pyramid; 10, carotico-tympanic canaliculi; 11, bristle showing course of Jacobson's nerve and its continuation, the small superficial petrosal nerve; 12, groove on the promontory for the tympanic plexus; 13, fenestra rotunda; 14, promontory; 15, a bridge of bone.

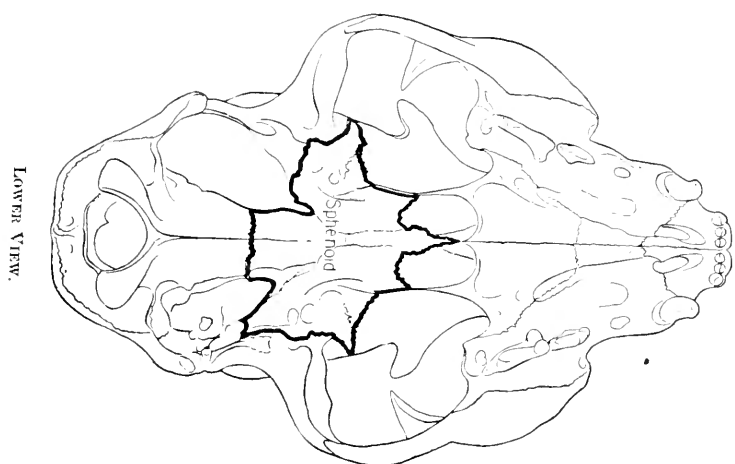
the hiatus Fallopii, and is known as the small superficial petrosal nerve. In the cat the tympanic branch passes from the jugular foramen, dorsal to the entotympanic part of the bulla and the bullar septum, to gain the tympanum, and the petrosal nerve escapes at the foramen between the anterior border of the petrous and the alisphenoid where the Vidian nerve enters.

### THE SPHENOID BONE.

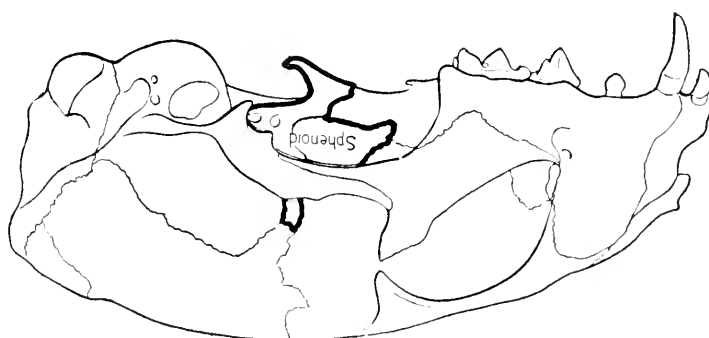
**General Description.**—The Sphenoid is a single and symmetrical bone, situated at the anterior end of the base of the cranium (Fig. 180). It articulates with all the cranial bones except the interparietal, and with three bones of the face, namely, the vomer and the two palatines. It is visible externally at the back of the orbits and at the lower part of the temporal and zygomatic fossæ. It forms the middle of the roof of the posterior nares, gives attachment to the posterior wall of the pharynx, and assists in closing the nasal chambers behind. On the inner surface of the skull it enters into the formation of the anterior and middle cranial fossæ for the cerebral lobes of the brain. It is perforated for the transmission of important nerves and vessels.

In shape it is irregularly five-sided (Fig. 181); with a long, transverse, posterior base; shorter, longitudinal sides; and curved, anterior sides which run inward and forward, but, inasmuch as the anterior angle is transversely truncated, do not meet in front. The middle portion of the bone, known as the **body**, is thick and narrow in front, but flatter, shallower, and wider behind. On each side of the body are two thin and curved outgrowths, known as the **small** and the **great wings** of the sphenoid. The bone is easily separated into two parts along a line which begins on each side on the anterior border of the great wing some little distance within the tip or widest lateral projection, and then runs inward and backward to the body, which it crosses transversely between the first and second pair of holes. The anterior, subtriangular part may be called the **anterior sphenoid**; the posterior, quadrate part may be called the **posterior sphenoid**. The middle region of the anterior sphenoid is formed by the **presphenoid**; the lateral masses or small wings are the **orbitosphenoids**. The portion of the body of the bone belonging to the posterior sphenoid is the **basisphenoid**; the large lateral parts, the great wings, are the **alisphenoids**.<sup>1</sup>

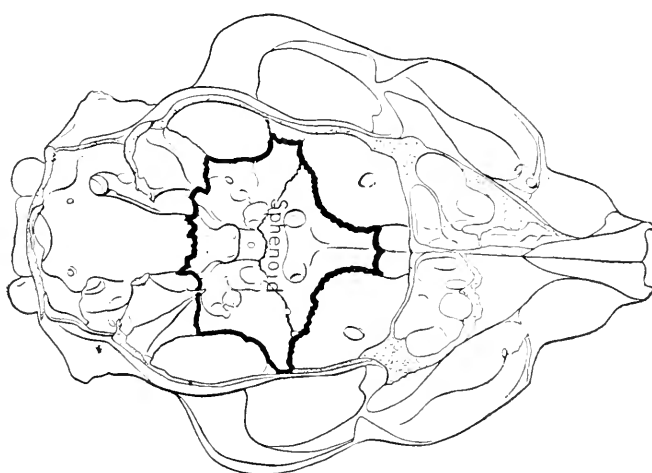
<sup>1</sup> From *ala*, a wing, and *sphenoid*.



LOWER VIEW.



SIDE VIEW.



UPPER VIEW.

FIG. 180.

POSITION OF THE SPHENOID BONE.

In the figure on the left, the Sphenoid is partly covered by the right Auditory Bulb.

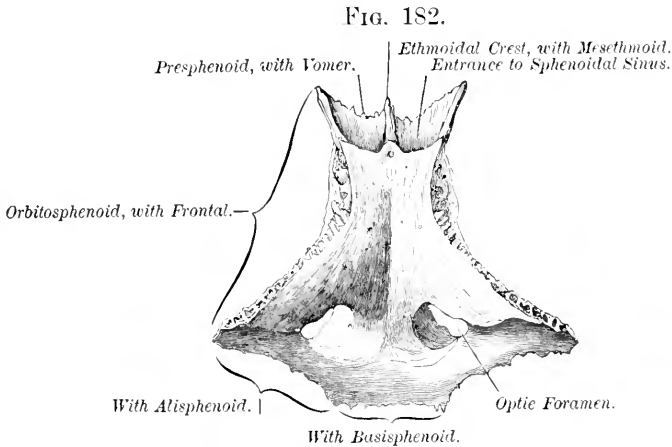




above are turned outward and prolonged upward as pointed wings. At the base of each wing is a large **optic foramen**.

The anterior sphenoid presents a superior, an inferior, an anterior, a posterior surface, and two lateral surfaces.

The **superior surface** (Fig. 182) has the outline of an irregular hexagon, whereof the anterior and posterior sides are transverse, the



PRESPHENOID AND ORBITOSPHEOIDS, INNER OR UPPER SURFACE.

long anterior lateral sides are directed backward and outward, and the shorter posterior lateral sides forward and outward. A line drawn between the acute lateral angles thus formed would divide the bone into a posterior third and an anterior two-thirds. The anterior margin is deeply emarginate on each side of the middle line, to articulate with the lower ends of the cribriform plate of the ethmoid. The median, forward prolongation is the **ethmoidal spine**, and is the upper border of the ethmoidal crest. Each anterior lateral border is emarginate, the concavity facing outward and forward; it is jagged, encroaching to a greater or less degree on the superior surface above and on the inferior surface behind, and articulates with part of the lower border of the frontal. The posterior lateral margins are thin and measurably straight; they form also the posterior margins of the wings. Each margin in its outer two-thirds or more is serrate, and articulates with the front border of the alisphenoid (Fig. 181); in its inner third or less it is free as the inner part of the upper margin of the sphenoidal fissure, and gives attachment to the dura of the brain. Its posterior angle is more or less prolonged into the anterior clinoid

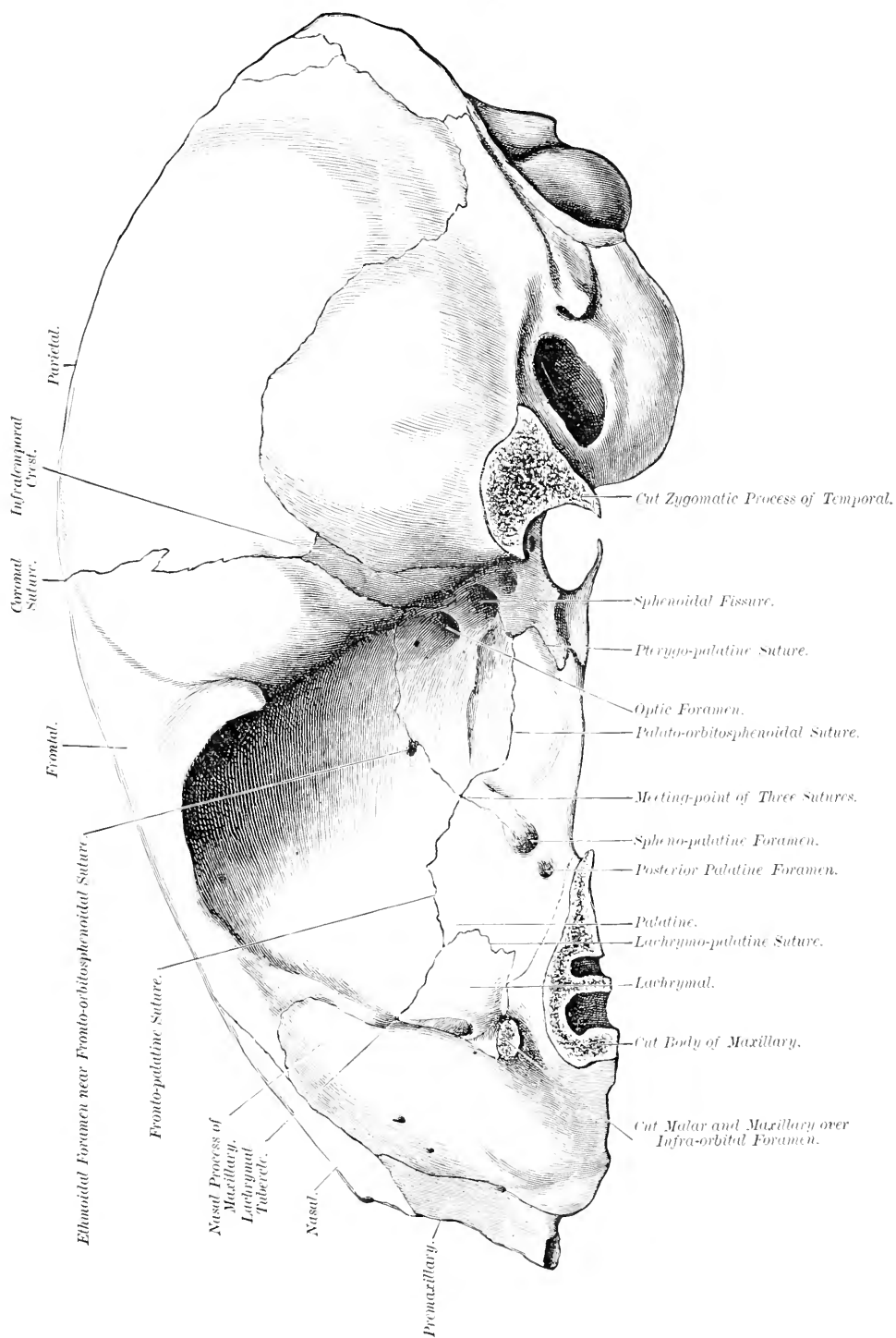
**process.** The transverse posterior margin is slightly emarginate and joins the upper anterior margin of the basisphenoid.

The narrow anterior part of the superior surface, included between the nearly straight parts of the anterior lateral borders, is gently concave from side to side and faces slightly forward as well as upward. It forms a floor for the olfactory fossa, and a support for the olfactory lobes of the brain. The lower part of the falx cerebri, the membranous partition which divides these lobes, is attached along the middle line. The part of the superior surface lying between the lateral angles, in front of the optic foramina, faces upward and backward, and is faintly convex from before backward and slopes inward and downward on each side to the middle line. The part of the wing lying outside of the foramen is slightly grooved transversely. The narrow part lying between the optic foramina is the transverse **optic groove**; it is sometimes sharply separated from the anterior portion by the continuation inward of a ridge from the anterior margins of the optic foramen. It faces backward at a still greater angle. It is smooth and convex from side to side. Its outer margins are rounded, and it passes gently into the orbital surface. The surface behind the optic groove is known as the **olivary eminence**. It faces almost directly upward, and is slightly convex from before backward. Its sides are prolonged forward and outward as the rounded posterior roots of the small wings or orbitosphenoids, and close the optic foramina behind. Its posterior angles are the **anterior clinoid**<sup>1</sup> **processes**.

Each **lateral or orbital surface** (Figs. 183, 185) is about twice as long as it is high. It is somewhat higher over the optic foramen and lower at the posterior end. Its lower margin is almost straight, and is serrated; it articulates with the vertical plate of the palatine for the anterior half and with the alisphenoid for the posterior half. The vertical anterior margin is irregularly arcuate, and joins the posterior border of the ethmoidal part of the vertical plate of the palatine. The superior border slopes from the front gradually up to the tip of the small wing, and then slopes abruptly downward and backward to the posterior margin. It is serrated, and sometimes bevelled at the expense of the surface throughout its course, except in the small posterior part which forms the margin of the sphenoidal fissure. From the front to the tip

<sup>1</sup> From (Gr.) *cline*, a bed, and *eides*, like.

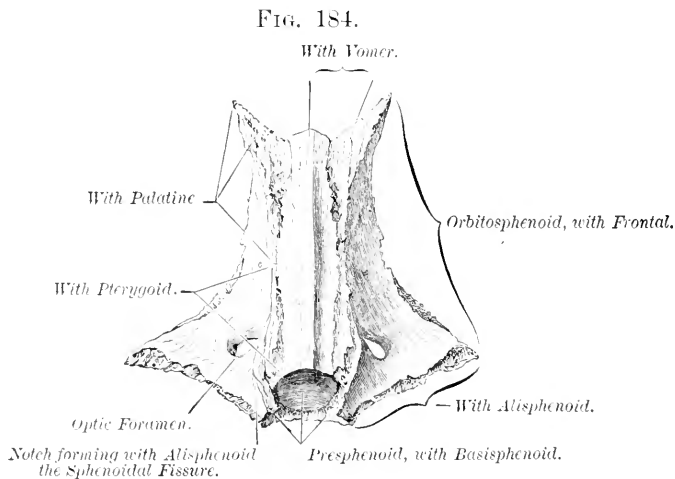
FIG. 183.



THE SKULL. LEFT SIDE. ZYGOMA AND LOWER JAW REMOVED TO SHOW ORBIT.

of the wing it articulates with the posterior part of the lower edge of the orbital plate of the frontal; behind this point, with the anterior edge of the alisphenoid. The posterior margin is short and directed downward and forward. A line, more or less prominent, which rises from the lower border, just behind the optic foramen, and, running obliquely forward, ends near the middle of the anterior margin, divides the lateral surface into an upper and a lower part. The lower part is concave from above downward, and in some specimens, owing to its narrowness, becomes a shallow groove; it is also concave from before backward. It ends behind at the groove for the sphenoidal fissure and gives origin to fibres of the external pterygoid muscle. The region above this line is concave from before backward for the anterior half, and slightly concave from above downward. It then begins to slope outward, becomes the under surface of the wing, and faces downward, forward, and outward. At its posterior part, underneath and behind the optic foramen, the lateral surface turns inward, and, facing outward and backward, becomes a groove running downward, backward, and inward which forms the inner wall of the sphenoidal fissure.

On the **inferior or external surface** (Fig. 184) of the presphenoid, in the middle line, is a smooth median ridge, the only part of the bone



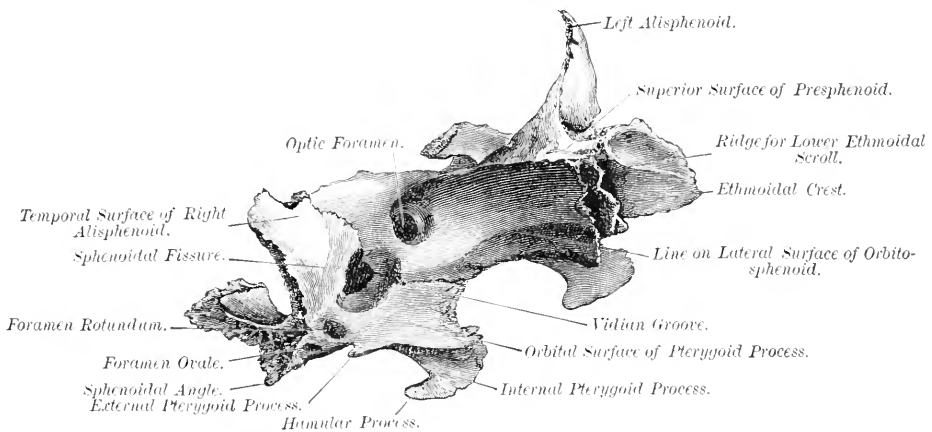
PRESPHENOID AND ORBITOSPHENOIDS, OUTER OR LOWER SURFACE.

which shows on the outside or base of the skull. It is rounded, and varies in width, but almost always presents a middle, flatter and wider part. On each side of this ridge, and between it and the lateral margins, is a rough articular surface, whereof all in front of the

middle is joined to the vertical plate of the palatine, and all behind that point articulates with the pterygoid process of the posterior sphenoid. The posterior end of the vomer embraces the anterior end of the median ridge on each side (Fig. 137). The anterior angles of the surface are produced in front; the anterior margin on each side is directed from the angle obliquely inward and backward to the median ridge, and articulates with the posterior edge of the expanded part of the vomer. From the anterior angles each lateral margin is evenly and decidedly emarginate back to the region of the optic foramen, where it turns inward and backward and articulates with the crest on the anterior surface of the pterygoid process, which forms the inner edge of the Vidian groove within the groove for the sphenoidal fissure. The posterior margin is very short and slightly emarginate.

The anterior surface of the presphenoid (Fig. 185) is almost

FIG. 185.

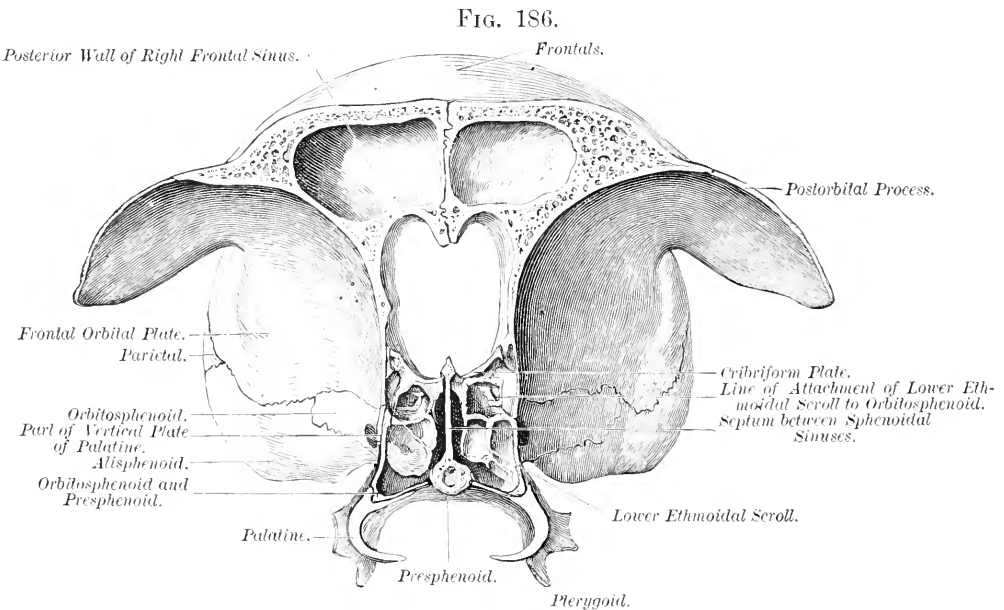


THE SPHENOID BONE. VIEWED FROM THE FRONT AND THE RIGHT SIDE.

entirely occupied by two large openings into the hollow interior of the bone. There is in fact nothing left but the thin margins articulating with the cribriform plate of the ethmoid and the vomer, and the median vertical partition, or **ethmoidal crest**, articulating with the posterior edge of the mesethmoid. The side margins of these openings are further forward than the upper and lower margins, owing to the greater length of the lateral surfaces, and, inasmuch as these surfaces are concave externally, they are convex internally and flare outward in front, each facing inward and forward and permitting much of the anterior part of the outer wall of each sinus to be seen from in front.

On each outer wall is a ridge which begins in front about half-way down and runs backward and upward to the upper end of the median partition on the superior border, thus forming a little oval pocket in the superior external angle. To the ridge is attached a lower posterior division of the ethmo-turbinal, or lateral ethmoid, which is known as the spheno-turbinal.

The interior of the presphenoid (Fig. 186) is almost entirely hollow, and is divided by a longitudinal vertical partition into two **sphenoidal sinuses**. The partition is often deflected from the middle line, in which case one sinus is much wider than the other. The sinuses



THE SKULL. TRANSVERSE SECTION JUST BEHIND POSTERIOR NARES, SEEN FROM IN FRONT.

are continued for a short distance only, or not at all, into the bases of the small wings. Sometimes they do not extend all the way back, but leave a small posterior part of the bone solid and composed of cancellous tissue. They are narrowed by a transverse ridge in front of the middle. The sinus in front of this constriction is occupied by the spheno-turbinal.

The posterior surface of the anterior sphenoid is small, circular, and rough for attachment to the basisphenoid.

The posterior sphenoid consists of two thin crescentic lateral plates, the alisphenoids, or great wings of the sphenoid, which curve upward, before and behind, and are united at the back part of their

inner edges by a central, flattened, transverse piece, the **basisphenoid**. From each alisphenoid, at its point of union with the basisphenoid in front, a plate-like horizontal process bearing secondary smaller processes projects downward and forward; it also projects under the anterior sphenoid, and is, in part, united with it: this is the **pterygoid**<sup>1</sup> process. The posterior sphenoid can be resolved into its parts, but usually the three pieces are found firmly united. The basisphenoid is the central triangular piece. The smaller front margin lies between the pterygoid processes, and the posterior margin is composed of as much of the posterior margin of the bone as lies between the small notches lateral to the large notches; the lateral borders, therefore, are directed from in front obliquely backward and outward.

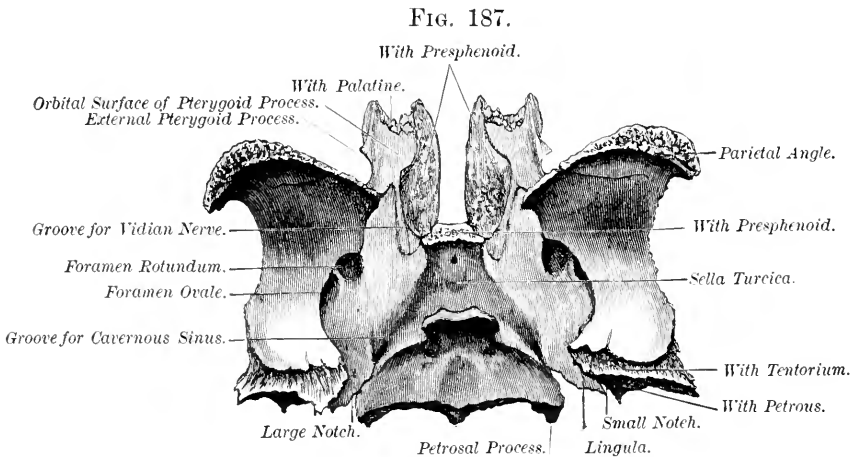
In many animals the pterygoids persist throughout life as distinct bones, but in the cat their union with the alisphenoid takes place so early that, except in very young specimens, it is impossible to find even sutures or lines which will indicate their boundaries. In the following description, therefore, they will be treated as processes of the alisphenoids.

The posterior sphenoid presents a superior and an inferior surface, and anterior, posterior, and lateral borders.

The **superior surface** (Fig. 187) comprises the superior surfaces of the basisphenoid and of the alisphenoids. It consists of two parts, a larger, central, flattened portion, principally basisphenoidal, and a curved, concave, lateral portion, wholly alisphenoidal. At the middle of the anterior border the superior surface is elevated into a transverse tuberosity which in front, by its quadrate, roughened, anterior surface, articulates with the back of the presphenoid just within the anterior clinoid processes. The posterior surface of this elevation slopes downward, backward, and on each side slightly outward to the plane of the general superior surface. It is concave in the centre longitudinally and transversely. At about the middle of the entire surface is a second transverse plate-like elevation which is slightly wider than the olivary eminence. The anterior surface of this elevation is convex from side to side, except just in the middle, where there is a slight depression. It is strongly concave from above downward. The upper edge overhangs the surface, which thus faces downward and forward. This elevation is called the **dorsum sellæ**. The fossa included between

<sup>1</sup> From (Gr.) *pterus*, a wing, and *eides*, like.

the olivary process and the dorsum sellæ is known as the **sella turcica**,<sup>1</sup> or, since it lodges the pituitary process of the brain, as the **pituitary**<sup>2</sup> **fossa**. It is usually longer than wide, and its lateral boundaries are marked to a greater or less degree by faint ridges, prolongations backward of the lateral margins of the anterior and posterior walls of the fossa; at times, but rarely, these ridges are elevated near the front into **middle clinoid processes**. In the pituitary fossa, in the front part of its middle line, is a small pituitary foramen which pierces the bone and gives exit to a vein; smaller secondary foramina leading into the substance of the bone are also sometimes observed. The upper margin of the dorsum sellæ is swollen and emarginate; the upper



POSTERIOR SPHENOID. SUPERIOR SURFACE.

angles are more or less prominent, and are known as the **posterior clinoid processes**. The dura mater of the brain, stretched from the anterior to the posterior clinoid processes, defines and deepens the sella turcica. The posterior surface of the dorsum sellæ, known as the **clivus**,<sup>3</sup> faces upward and backward. It is wider below than above, is slightly concave in both directions, and is pierced by venous foramina. It is crossed by a venous sinus and an artery. The sides are directed downward, outward, and backward. They are usually notched at their bases for the passage of the sixth pair of cranial nerves. The lower margin of the dorsum sellæ is also the posterior margin of the body of the bone, and comprises the middle third of the entire posterior border. It is rough and irregular, articulating with the front of

<sup>1</sup> A Turkish saddle.

<sup>2</sup> From *pituita*, slime.

<sup>3</sup> A slope.



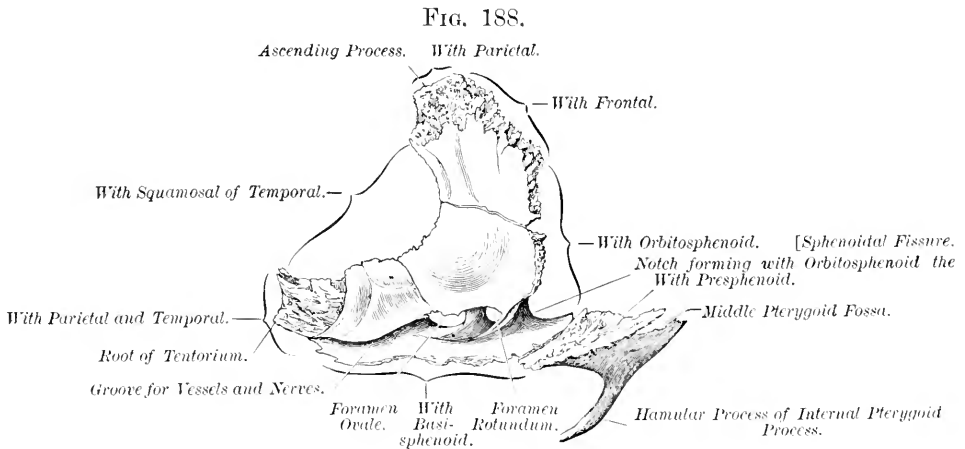
the basioccipital. Its outer angle, known as the **petrosal process**, is separated on each side from the remaining part of the border by a deep, narrow notch, directed inward as well as forward. The petrous of the temporal is applied to the under surface around the notch, and a little pointed process from the entotympanic fills the notch which is part of the middle lacerated foramen of the skull.

The rest of the flattened part of the upper surface of the basisphenoid consists of a narrow strip on each side of the sella turcica, the long axis of which is directed obliquely inward and forward. It is limited within, beginning in front, by the inner edge of the pterygoid process, the outer side of the olivary eminence, the side of the sella, and the outer side of the clivus. Its external margin is in front the outer edge of the pterygoid process and for the rest of the distance a sharp crescentic border, which is at once the overhanging upper margin of the foramen rotundum and foramen ovalis and the inner edge of the alisphenoidal part of the tentorium. The jagged margin of the pterygoid process limits the region in front. Behind, overlapped extracranially by the petrous, is the oblique external margin of the notch already mentioned. Just lateral to its outer angle and medial to the beginning of the posterior margin of the tentorial part is a smaller notch, which, with the petrous, forms a foramen leading into the tympanic cavity in the temporal bone. It represents the outer part of the middle lacerated foramen, and transmits the Vidian and small superficial petrosal nerves. The little point between the two notches is known as the **lingula** of the sphenoid.

The region anterior to the olivary eminence may be considered the superior surface of the pterygoid process. It is almost square; the anterior border is jagged, and bevelled at the expense of the anterior third of the surface. Its inner third is flat and rough, and articulates with the presphenoid (Figs. 187, 188). An oblique line runs backward and outward from the middle of the outer edge of this rough area to join the sharp anterior external edge of the plate which forms the floor of the sphenoidal fissure and the roof of the round foramen. In front of this line is an external anterior triangle which is concave from side to side and inclines upward and outward. The outer border of this surface is directed slightly outward, and is produced at its middle into a spine, called the **external pterygoid process**. The surface is seen at the lower posterior part of the orbit, where it is

continuous with the orbital surface of the vertical plate of the palatine. Behind this orbital surface, the upper surface of the pterygoid process on the outer side forms the floor of the sphenoidal fissure. It is faintly concave from side to side and nearly flat or gently convex from before backward, and faces upward. Near its inner side is a well-defined longitudinal groove which terminates posteriorly in a foramen, the anterior opening of the Vidian canal. The groove may be partially converted into a canal situated on the inside of the sphenoidal fissure.

On each side of the sella is a faintly marked longitudinal depression for the cavernous sinus; this depression ends behind at the angle of the notch for the temporal bone in a groove for the carotid artery, and is overlapped on the outside by a ridge on the lingula. Lateral to this depression the surface is flattened and supports the



LEFT ALISPHENOID, INNER ASPECT.

Gasserian ganglion. It passes in front into the floor of the sphenoidal fissure; at the side it is continued under the sharp, overhanging, inner border of the elevated portion of the general upper surface and between vertical partitions, as the floor of the foramen rotundum and the foramen ovale. Behind these foramina it curves upward and forms under the edge of the tentorium a fossa for the back of the ganglion.

The **foramen rotundum**, or round foramen, lies next to the sphenoidal fissure, and pierces the bone obliquely, passing forward, outward, and slightly downward. At the back of its inner wall is a small foramen, which appears to be constant and leads into the interior of the bone.

The **foramen ovale**, or oval foramen, is a little larger or more oval

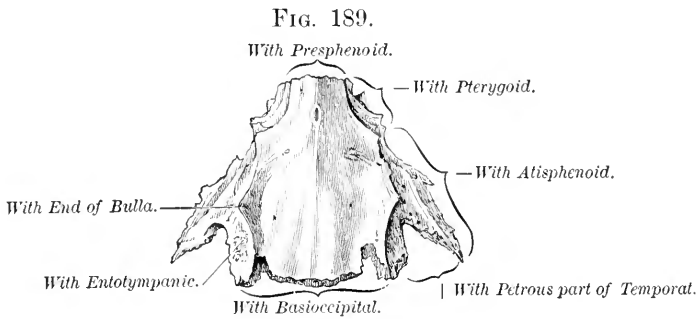
than the round foramen, and is directed more obliquely toward the side of the skull; a small foramen is often found piercing its inner wall.

Each elevated and concave lateral part of the upper surface is sickle-shaped, and is formed by the alisphenoid (Fig. 188). It presents inner, posterior, anterior, outer, and superior borders. The sharp inner border is elevated and overhangs the flat surface lying medial to it. It is directed from behind forward and somewhat inward, and is emarginate at its middle, over the entrance to the oval foramen. It forms in front the outer part of the upper margin of the sphenoidal fissure, and terminates by making an obtuse angle with the anterior border. The anterior border is arcuate and directed upward, outward, and backward, so that it appears as an upper border to the prominent front part of the surface. Its inner or median half is straighter and thinner than the rest, and is serrated to articulate with the posterior border of the orbitosphenoid. The outer half, or less, is broader and jagged; it curves backward and joins the posterior border of the vertical plate of the frontal. The superior border varies in shape and direction: sometimes it is straight, sometimes pointed; it may run almost horizontally or may assume a vertical position. It is always thin, and overlaps the produced lower anterior angle of the parietal. The outer border is deeply emarginate, more especially in front, the concavity facing outward and backward. It is sharp and slightly serrated, but bevelled at the expense of the lower surface to articulate with the front of the squamous of the temporal. The posterior border is bevelled in both directions; the upper rough surface is overlapped by the tentorial plate of the parietal bone (Fig. 170). The lower part is a narrow, triangular, transverse fossa which is applied to the rounded anterior border of the petrous portion of the temporal, lateral to the hiatus Fallopii. This posterior end of the alisphenoid is the alisphenoidal root of the tentorium.

The superior surface of the alisphenoid is deeply concave from before backward, rising higher in front than behind. It is also somewhat concave transversely. It enters into the formation of the middle cranial fossa. Near the middle of its anterior border is seen a foramen from which a groove crosses the surface transversely.

The **inferior surface** of the posterior sphenoid comprises three parts, a central portion of the body, an inferior surface of each wing, and an inferior surface of each pterygoid process (Fig. 190).

The part contributed by the basisphenoid is easily distinguished (Fig. 189). It consists principally of a central, flattened area, which is quadrate, as long as it is wide, and slightly concave transversely, on each side of the middle line. The anterior angles are cut off by the rounded inner posterior angles of the pterygoid processes, leaving a short straight transverse anterior border between them. The transverse posterior margin is much wider and is very slightly emarginate on each side of the median line; the posterior angles are produced, and each forms the inner lip of the large notch for the temporal. The lateral boundaries of this flattened area are sharp longitudinal ridges which run from its posterior angles nearly to the posterior margins of the pterygoid plates. On each side a triangular roughened area is

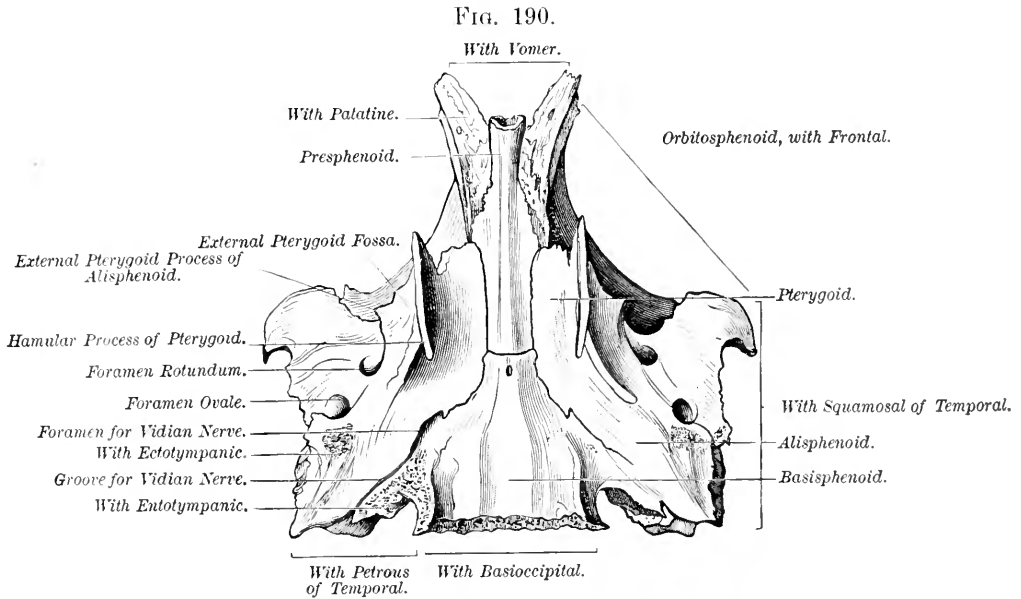


BASISPHENOID, OUTER OR LOWER SURFACE.

included between this ridge and an oblique groove which runs inward and forward from the notch on the outside of the lingula behind to the foramen or slit just behind the pterygoid plate in front. This area slopes slightly upward and outward and articulates with the anterior end of the entotympanic portion of the auditory bulla. The posterior margin of this triangular articular surface is, in general, transverse, but is deeply incised by the temporal notch; the inner margin is longitudinal and bevelled. The outer margin, which is directed forward and inward, is also bevelled, and is produced on the upper surface as a more or less prominent ridge overlapping the anterior angle of the notch and forming an outer boundary to a groove for the carotid artery.

The under surface of the pterygoid process (Fig. 190) is sharply defined behind, only at its inner half, as a thin margin overlapping the basisphenoid and rounding forward into the straight thin inner margin which overlaps the presphenoid. This prolongation inward of the

pterygoid is termed the **vaginal**<sup>1</sup> process. An imaginary line drawn from this thin posterior margin to the posterior edge of the round foramen marks the approximately outer posterior limit of the pterygoid process. The outer border begins, behind, in the sharp, crescentic, posterior margin of the round foramen, and runs forward, downward, and slightly inward to end in the sharp anterior angle. It is thin, and about half of its length is prolonged into a variable, external pterygoid



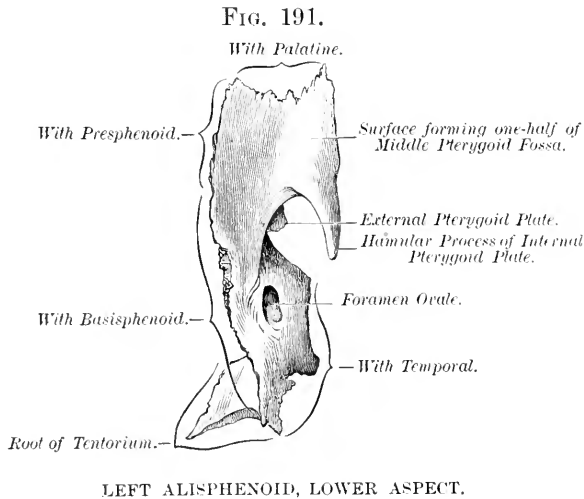
THE SPHENOID BONE, EXTERNAL OR LOWER ASPECT.

plate or process which, when well developed, points downward, backward, and outward. The anterior margin is transverse and jagged; it joins the posterior part of the horizontal plate of the palatine. The inferior surface of the pterygoid process is divided into two unequal parts by the longitudinal internal pterygoid plate or process, which projects downward.

The internal pterygoid process is a thin plate, prolonged beneath and behind into a **hamular process**. Its lower border begins on the front margin just within the anterior external angle and runs backward and downward to terminate in the tip of the hook. It is usually sinuate, curving first outward, then inward, then outward again. The posterior border begins behind where the lower border ends, and is deeply emarginate. It curves upward and forward to a point opposite

<sup>1</sup> From *vagina*, a sheath.

the external pterygoid process; here it turns abruptly and runs backward, outward, and upward as a mere ridge parallel with the external border of the whole pterygoid, and ends on the surface of the alisphenoid opposite the oval foramen. The hamular process varies in development and general direction; the tendon of the tensor palati winds about it. The inferior surface, between the internal pterygoid process and this ridge within and the external border without, is concave transversely and forms a long narrow fossa, the **external pterygoid fossa** (Fig. 192), which affords attachment to the internal ptery-



goid muscle. The inner portion of the inferior surface thus divided is smooth, quadrate, longer than wide, and descends gradually from the inner border to the lower border of the internal pterygoid and hamular processes. The lower surfaces of the two pterygoids form the roof and outer walls of the deep **middle pterygoid fossa**.

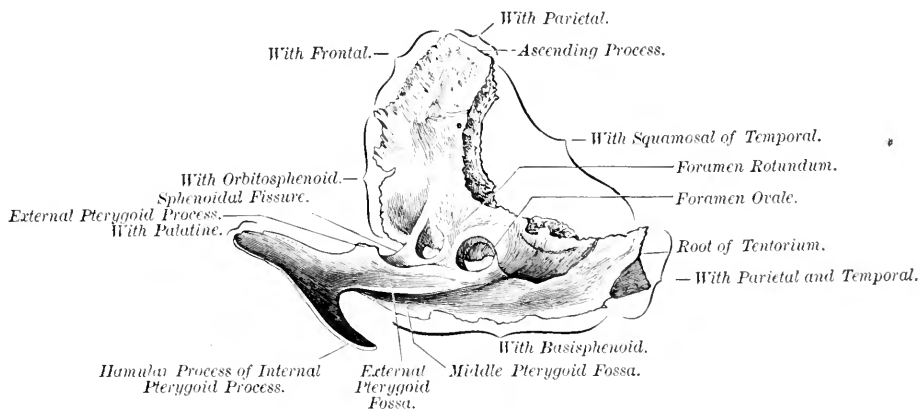
The alisphenoidal part of the under surface of the posterior sphenoid (Fig. 192) has the general outline of the alisphenoidal part of the upper surface, namely, that of a rude crescent, whereof the concavity faces outward. The upper surface being concave from before backward, this surface is of course convex from before backward. For convenience of description it may be divided into four regions, an upper or temporal, a middle or orbital, a zygomatic, and a posterior or scaphoid.

The **temporal region** comprises the anterior and superior prominent horn of the crescent. It is sharply defined from the orbital region by a longitudinal roughened line, the **infratemporal ridge**

(Fig. 183), which if prolonged behind would strike the tip of the posterior horn of the crescent. The temporal region is almost vertical, and faces outward and slightly forward. Its anterior arcuate border is thick and jagged and articulates with the lower posterior part of the vertical plate of the frontal bone. The upper border, more or less straight, joins the parietal, and is known as the **parietal angle** of the bone; the posterior emarginate border is overlapped by the squamous of the temporal. The temporal region is slightly rougher than the rest of the surface, and forms part of the side of the temporal fossa.

The **orbital region** has as its outer boundary the roughened line already mentioned, and as its anterior boundary the remaining part of the oblique anterior border of the alisphenoid. The inner boundary

FIG. 192.



LEFT ALISPHEOID, OUTER ASPECT.

is the outer upper margin of the sphenoidal fissure. The posterior, artificial limit is the continuation outward of the ridge-like root of the partition dividing the sphenoidal fissure from the foramen rotundum. The surface of this region is smooth and flat and faces forward and downward; it forms the small posterior bony wall of the orbit. The inner part of the orbital portion slopes inward, upward, and backward, so as to form an outer wall to the sphenoidal fissure.

The **zygomatic region** lies directly behind the orbital region, and is triangular, the sides being nearly equal. The anterior boundary is the posterior boundary of the orbital region; the external boundary is the middle portion of the emarginate, thick, cleft, and jagged external border of the alisphenoid, articulating with the squamous of the temporal opposite the inner end of the glenoid cavity. The inner

oblique boundary is the outer boundary of the external pterygoid fossa, and its continuation behind the foramen ovale. In its anterior internal angle is the lower opening of the foramen rotundum, piercing the bone obliquely outward, forward, and downward, so that when viewed from below the inner or upper opening is not visible. Separated from this opening by a flattened partition is the lower opening of the foramen ovale, which also runs obliquely through the bone. A little behind and lateral to the oval foramen is the posterior angle of this region, which is prominent and marks the anterior termination of a roughened articular area for the ectotympanic. It may be called the **angular spine**. The zygomatic region slopes away from the foramen outward and upward, and from behind forward and slightly upward, but faces mainly downward, and lies in the same plane as the glenoid cavity.

The **scaphoid region** (Fig. 190) is what remains of the lower surface of the alisphenoid. Its boundaries are: in front, the inner boundary of the zygomatic region; within, the oblique groove for the Vidian nerve; without, the outer, jagged, nearly straight, posterior part of the general external border, joining the squamous of the temporal bone; and behind, a sharp, transverse, irregularly serrated border which abuts against the petrous of the temporal bone. The inner part of the surface is a shallow groove running obliquely backward and outward. The inner front part is known as the **scaphoid fossa**, and gives origin to the tensor palati muscle. The posterior part runs slightly upward under the overhanging front of the auditory bulla, forming the roof of the long canal for the Eustachian tube and a small anterior part of the roof of the tympanum. The outer part of the surface, principally occupied by a narrow, oblique, and roughened area, for articulation with the entotympanic portion of the bulla, is marked by longitudinal grooves, producing between the surface and the bulla the Glaserian fissure and the canal of Huguier.

**Nomenclature.**—Sphenoid is from two Greek words, *sphen*, a wedge, and *eides*, like. It was introduced by Galen, and refers not so much to its shape as to its wedge-like function in the base of the human skull. The Latin names *os sphenoidale*, *os sphenoidum*, and *os sphenoides*, the French *le sphénoïde*, and the German *das Keilbein*, all have the same signification. Another group of names is based on the likeness of the bone to a flying insect: namely, *os sphecoideum*,



*os vespiforme*, *das Wespenbein*, from the Greek, Latin, and German words for a wasp.

**Articulation.**—The sphenoid articulates with the occipital, the temporals, the parietals, the frontals, the palatines, the ethmoid, and the vomer.

**Muscular Attachments.**—The following muscles are attached to the sphenoid: to the temporal surface of the alisphenoid, the **temporal**; to the orbital surface of the orbitosphenoid, the **external pterygoid** and most of the small **ocular** muscles; to the external pterygoid fossa, the **internal pterygoid**; to the basisphenoid, the **pharynx**; and to its scaphoid fossa, the **tensor** and **levator palati** muscles.

**Ossification.**—The different primary centres of ossification coalesce to form eight elements,—namely, the two orbitosphenoids, the two alisphenoids, the two pterygoids, the presphenoid, and the basisphenoid. At birth the orbitosphenoids have joined the presphenoid and the alisphenoids have coalesced with the basisphenoid; the pterygoids, however, are still partially distinct elements, the separating sutures dividing the external pterygoid fossæ from end to end and meeting the thin inner margins of the vaginal processes on a line with the foramina ovalia.

#### VARIATIONS IN THE SPHENOID.

##### VARIATIONS IN SIZE.

The following measurements show the differences in size observed in twenty-five sphenoids:

- (1) The maximum length is the distance from the anterior end of the orbitosphenoid to the posterior border of the basisphenoid;
- (2) The maximum width is the distance between the outer edges of the tips of the parietal angles;
- (3) The maximum height represents the distance from the edge of the hamular process to the tip of the parietal angle, taken at right angles to the inferior surface of the bone.

On the superior surface are measured:

- (4) The median length of the presphenoid;
- (5) The distance between the outer edges of the optic foramina;
- (6) The distance between the tips of the orbitosphenoids;
- (7) The distance from the anterior edge of the parietal angle to the extreme posterior outer angle of the alisphenoid;

(8) The distance from the anterior edge of the parietal angle to the anterior end of the orbitosphenoid ;

(9) The width of the posterior sphenoid at the posterior angles ;

(10) The width of the anterior sphenoid taken in its narrow part just before the lateral borders begin to turn outward on the small wings ;

(11) The width of the basisphenoid taken on the posterior border between the outer edges of the lingula ;

(12) The median length of the basisphenoid from the olivary eminence to the posterior border.

On the inferior surface are measured :

(13) The median length of the presphenoid ;

(14) The median length of the basisphenoid ;

(15) The extreme anterior width of the presphenoid ;

(16) The distance between the anterior ends of the hamular processes ;

(17) The distance between the tips of the external pterygoid processes ;

(18) The distance between the inner edges of the foramina ovalia ;

(19) The distance between the sphenoidal angles (the angle behind the foramen ovale).

## MEASUREMENTS OF TWENTY-FIVE SPHENOID BONES.

(1)	Length . . . . .	35	35	34	33	33	33	33	33	33	32	32	32	31	31	31	30.5	30	29	29	29	29	29	28		
(2)	Width . . . . .	37	35	35	37	36	36	35	35	34.5	34	36.5	35.5	35	33	40	32	35.5	33	33	35	32	33	35		
(3)	Height . . . . .	21	19	20.5	23.5	20.5	17.5	19.5	17	19	18.5	20	19.5	17	19.5	18	17.5	17	18	17	17.5	17.5	16.5	18		
<i>On superior surface.</i>																										
(4)	Presphenoid length . . . . .	17.5	18.5	17	16	19	19	18	16	18	17.5	17	18	16	18	15	17	15	17	15	16	16	17.5	15.5	15	
(5)	Between optic foramina . . . . .	11.5	10	11	10.5	10	10.5	10	10	10	11	10.5	9	10	11	9	9	10	10	9	8.5	9.5	9	10		
(6)	Maximum presphenoid width . . . . .	26	23	28	29	26	24	26	27	22.5	25	25	26	24	25	24	23	24	28	25	22.5	23	22.5	22	24	
(7)	Lateral posterior sphenoid length . . . . .	20	16.5	19	20	18.5	18	19	15	19	18	19	16.5	16.5	18	17	17	17	16	17	17	17	16	16	18	
(8)	Lateral anterior sphenoid length . . . . .	22	25.5	25	27	25	23	24	24	23	20	24	23	22	22	24	22.5	21	22	22	21.5	21	20	21	19	21
(9)	Between posterior angles . . . . .	27	30.5	31	30	29	32.5	31	30	29.5	29.5	30	30	28	29.5	28.5	28	29	30	31	30	29	28	28.5	29	
(10)	Anterior presphenoid width . . . . .	9	7	11	10	7	6	8	9	6	10	8	7	8	7	9	12	8	8	7	8	8	8.5	5	8	
(11)	Basisphenoid width . . . . .	22	19.5	22.5	19	20	18	20	20	20	22	20.5	18	20	22	20	19	18.5	20.5	19	20	18.5	17.5	19.5	18	19
(12)	Basisphenoid length . . . . .	13	12	12	13	10.5	11	12.5	11	12.5	12	12	12	12	11	11	11	12	10	10	10	10	11	10.5	9	
<i>On inferior surface.</i>																										
(13)	Presphenoid length . . . . .	16	14	17.5	17	15	17	16	15.5	18	16	18	15	16.5	15	14	14.5	12	12.5	13	12	13	10.5	13	14	11
(14)	Basisphenoid length . . . . .	14	14	11	11	10	12	12.5	11	13	12	12	13	12	12.5	11	11	11.5	12.5	10	10.5	10.5	10.5	11	12	9
(15)	Presphenoid width . . . . .	12	10.5	11	13	11	12	12.5	11.5	11	12	10.5	10	11	11.5	12	11	11	10.5	10	10.5	10	10	10	11	11
(16)	Between hamular processes . . . . .	12	13	16	15	12	14	13.5	13	13.5	14	13	15	13	13	11	12.5	14	11	12	12.5	12	11	12	11	11
(17)	Between external pterygoids . . . . .	20	17	17	18	18	18	18	19.5	16.5	16	16.5	19	15	17	16	18	18.5	16	15	13	15	16	13.5	15	17
(18)	Between foramina ovalia . . . . .	21	20.5	20	20	18	21	20	20	18.5	20	21	21	20	19.5	19.5	19.5	20	19	18.5	19	18	19	18	18.5	19
(19)	Between sphenoidal angles . . . . .	30.5	31	30	31	29	31	30	29	30.5	30.5	30	32	26	31	28	31	28	30	29	26	28	29	28	29	29

## VARIATIONS IN FORM AND DEVELOPMENT.

In some specimens the superior surface of the presphenoid is reduced to a very narrow median strip by the increased width of the marginal frontal articular surfaces.

The **optic groove** may be sharply defined from the olfactory surface by a continuous ridge, which is either transverse or V-shaped. In one specimen examined, the middle of the optic groove exhibited a pointed triangular spine, which was directed backward and, by almost touching the olivary eminence, formed an incomplete transverse canal.

In the majority of sphenoids the **anterior clinoid processes** are well developed; occasionally they are prolonged backward as long spines. Not infrequently the posterior edge of the orbitosphenoid, just lateral to the anterior clinoid process, presents a second small process; the intermediate groove lodges the ophthalmic artery.

The sides of the **sella turcica** rarely show middle clinoid processes. When present they are very small and placed near the anterior end. The diameters of the sella turcica are variable, even in sphenoids of the same size; its lateral boundaries are occasionally clearly defined as far back as the lingula.

In some specimens the large notch in the posterior border, medial to the lingula, is bridged by bone and converted into a foramen.

The sharp edge of the alisphenoid which overhangs the inner openings of the foramina varies widely in form and development. It is sometimes so deeply emarginate, especially behind, that the elevated part of the great wing is reduced to a narrow strip, and the lower flat medial part is largely uncovered; in a few specimens the extracranial opening of the foramen ovale was visible when the bone was viewed squarely from above.

The inner surface of the **parietal angle** may be almost completely occupied by a roughened surface for the frontal; in other cases this articulation is confined to the free edge only. A true parietal articulation appears to be always present, although in extent sometimes greatly reduced.

The small meningeal **foramen** between the small and great wings is always confined to the suture; it is generally very small, but may reach a considerable size.

The **anterior aspect** of the anterior sphenoid in some specimens is very much wider than high. The speno-turbinal ridges on the outer

walls of the sinuses are usually distinct and placed low down; they may, however, be obscure or confined almost to the upper borders.

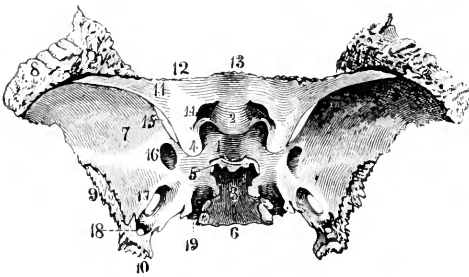
The **lower surface** of the presphenoid sometimes exhibits a very strong median keel. The internal and external pterygoid processes present variations in size and form; it should be remembered that they are easily destroyed by maceration and cleaning.

The groove on the lower surface of the posterior sphenoid which separates the basisphenoid from the alisphenoid and lodges the Vidian nerve in some specimens is but faintly marked. The course of the small internal carotid artery toward the middle lacerated foramen is occasionally indicated on the sphenoid by a short groove passing across the base of the lingula from the angle of the large notch to the Vidian groove. This groove with the groove on the superior surface of the bulla in front of the smaller entotympanic spine forms a small carotid canal.

### HUMAN SPHENOID BONE.

By reason of its irregular shape, its many processes, and its complex articulations with so many other bones, the sphenoid presents more difficulties to the student than any other bone in the human

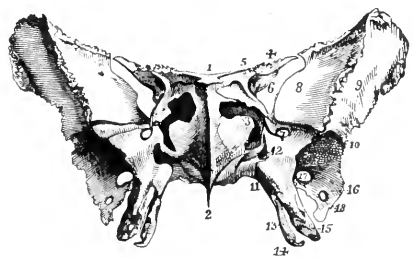
FIG. 193.



UPPER VIEW OF THE SPHENOID BONE.

1, sella; 2, olivary eminence; 3, clivus; 4, anterior clinoid process; 5, posterior clinoid process; 6, posterior border of the body; 7, cerebral surface of the great wing; 8, articular surface for the frontal bone; 9, articular border for the temporal bone; 10, spinous process; 11, small wing; 12, border articulating with the orbital plate of the frontal bone; 13, border joining the ethmoid bone; 14, optic foramen; 15, sphenoidal fissure; 16, foramen rotundum; 17, foramen ovale; 18, foramen spinosum; 19, groove on the lingula for the internal carotid artery.

FIG. 194.



FRONT VIEW OF THE SPHENOID BONE.

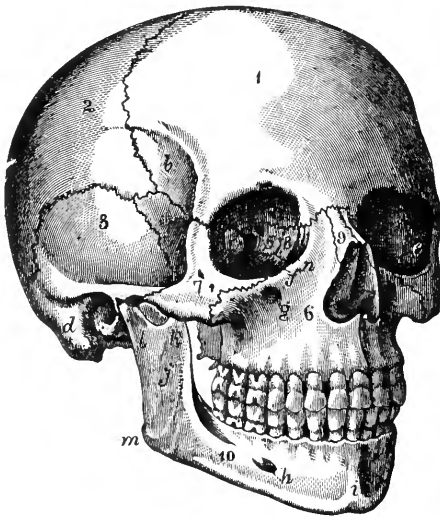
1, ethmoidal process; 2, sphenoidal crest and rostrum for joining the nasal plate of the ethmoid bone and the vomer; 3, entrance of the sphenoidal sinuses; 4, small wing; 5, optic foramen piercing its base; 6, sphenoidal fissure; 7, foramen rotundum; 8, orbital surface of the great wing; 9, temporal surface of the same; 10, ridge separating the temporal and zygomatic surfaces; 11, vaginal process; 12, Vidian canal; 13, internal pterygoid plate; 14, hamular process; 15, external pterygoid plate; 16, angular process; 17, foramen ovale; 18, foramen spinosum.

skeleton. It will be readily understood if the more generalized type has been first studied.

Compared with the sphenoid of the cat, it is much compressed from before backward, and thus appears to be relatively broader; it presents,

however, few structural changes, only such as result from antero-posterior compression. The anterior sphenoid is scarcely developed in front of the optic foramina (Fig. 193), hence the great wings, the alisphenoids, project beyond the anterior end of the body. The pterygoid processes, in place of projecting as thin plates forward under the anterior sphenoid, are narrow and at right angles to the inferior surface, and each is attached between the foramen rotundum and the foramen ovale, which are thereby widely separated. The posterior sphenoid does not extend backward beyond the foramina ovalia, which thus pierce the alisphenoids close to the posterior margin. The great wing exhibits an important feature which is rudimentary in the great wing of the cat's sphenoid. The vertical part of the alisphenoid of the cat presents only intracranial and extracranial surfaces, and hence is linear in trans-

FIG. 195.



THE SKULL, SEEN PARTLY IN FRONT AND ON THE RIGHT SIDE.

1, frontal bone; 2, parietal bone; 3, temporal bone, squamous portion; 4, sphenoid bone, temporal surface of its great wing; 5, ethmoid bone, orbital surface; 6, maxilla; 7, malar bone; 8, lachrymal bone; 9, nasal bone; 10, mandible; a, orbital plate of the frontal bone; b, temporal surface; c, orbital surface of the large wing of the sphenoid bone; d, mastoid portion of the temporal bone; e, orbital surface of the malar bone; f, orbital plate of the maxillary; g, infraorbital foramen; h, mental foramen; i, symphysis; j, ramus; k, coronoid process; l, condyloid process; m, angle; n, lachrymal fossa.

verse horizontal section; in the human alisphenoid this region of the extracranial surface is drawn outward, along a line extending downward parallel with the posterior border, into a sharp malar crest (Figs. 194, 195), which articulates with a corresponding crest on the malar bone, and thus separates the orbital cavity in front from the temporal and zygomatic fossæ behind. The extracranial surface is thereby divided into a true orbital surface, which faces forward and inward, and a lateral surface, which faces outward. In section the vertical part of the great wing is triangular.

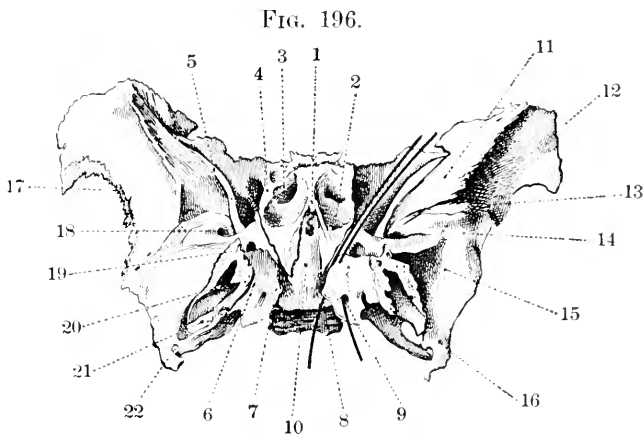
If the bone be now examined in detail, the student will observe that the anterior aspect of the

presphenoid is covered on each side of the ethmoidal (or sphenoidal) crest by a thin pyramidal bone which exhibits an opening into the corresponding sphenoidal sinus. This bone is the **spheno-turbinal**,

completely coalesced with the sphenoid. The ethmoidal crest is continued on the inferior surface of the anterior sphenoid as the **sphenoidal rostrum**. The **sphenoidal fissure** extends outward and separates completely the small and great wings.

The anterior sphenoid as a whole is bent downward from the plane of the posterior sphenoid.

The **pterygoid processes** arise from the body of the bone in common with the great wings and posterior to the anterior sphenoid, with which they are not connected. Each process consists of two parts, called plates; the **outer plate** corresponds with the part of the alisphenoid of the cat which bears the small external pterygoid process; the **inner plate** corresponds with the pterygoid bone. The anterior edges of the two plates are united, except at the inferior part, where they diverge and articulate with the pyramidal process of the



THE SPHENOID BONE, INFERIOR ASPECT.

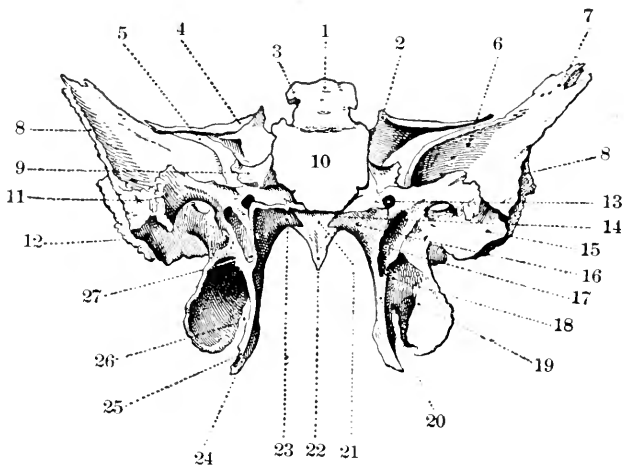
1, sphenoidal rostrum; 2, speno-turbinal; 3, opening of sphenoid sinus; 4, orbital margin of speno-turbinal; 5, sphenoidal fissure; 6, pterygoid process; 7, vaginal process; 8, bristle passed through basipharyngeal canal; 9, bristle through pharyngeal canal; 10, sphenoidal crest; 11, orbital surface of great wing; 12, temporal surface; 13, speno-maxillary crest; 14, infratemporal crest; 15, zygomatic surface; 16, angular spine; 17, squamous border; 18, foramen rotundum; 19, Vidian canal; 20, pterygoid fissure; 21, foramen ovale; 22, foramen spinosum.

palatine bone. Their posterior edges are separated by the **external pterygoid fossa**. The **vaginal process** from the root of the inner plate is well marked, and, owing to the antero-posterior compression of the skull, articulates by its edge with the vomer, completing with it a dorsal longitudinal **basipharyngeal canal**. Its ventral surface presents a groove which the palatine bone converts into a **pharyngeal canal**.

Below the orbital surface (Figs. 194, 196) of the great wing and separated from it by a **spheno-maxillary crest** is the external opening

of the **foramen rotundum**; below this foramen and continued on the front of the pterygoid process is a **spheno-maxillary** surface which forms the posterior part of the spheno-maxillary fossa. In the medial superior corner is the anterior opening of the **Vidian canal**. The lateral surface of the great wing is divided by a horizontal **infratemporal crest** into an upper temporal surface and a lower zygomatic surface. The **scaphoid fossa** is limited to an oval depressed area on the upper part of the posterior edge of the inner pterygoid plate. The **hamular process** is a curved rod, which is very variable in size and shape. The **foramen ovale** is relatively much larger than the corresponding opening in the sphenoid of the cat; lateral to it is a smaller opening, the **foramen spinosum**, for the meningeal vessels, which is not present in the cat.

FIG. 197.



THE SPHENOID BONE. POSTERIOR ASPECT.

1, dorsum sellæ; 2, anterior clinoid process; 3, posterior clinoid process; 4, small wing; 5, sphenoidal fissure; 6, great wing, intracranial surface; 7, parietal angle; 8, squamous border; 9, carotid groove; 10, posterior surface of body; 11, spheno-petrosal lamina; 12, infratemporal crest; 13, Vidian canal; 14, basipharyngeal canal; 15, zygomatic surface of great wing; 16, pharyngeal canal; 17, scaphoid fossa; 18, pterygoid fossa; 19, external pterygoid plate; 20, internal pterygoid plate; 21, sphenoidal crest; 22, sphenoidal rostrum; 23, vaginal process; 24, hamular process; 25, groove for tensor palati muscle; 26, pterygoid fissure closed by palatine bone; 27, pterygoid process.

The region of the great wing behind the foramen ovale is reduced to a narrow strip which is bent sharply dorsally and backward from the inferior surface and is known as the **spheno-petrosal lamina**. In this way the posterior end of the vaginal process (the **vaginal tubercle**) and the posterior opening of the Vidian canal are brought close to the apparent posterior margin of the bone. Medial to the spheno-petrosal lamina is the **lingula**, much reduced in size, but supporting a more clearly defined **carotid groove**. A short groove leading ventrally



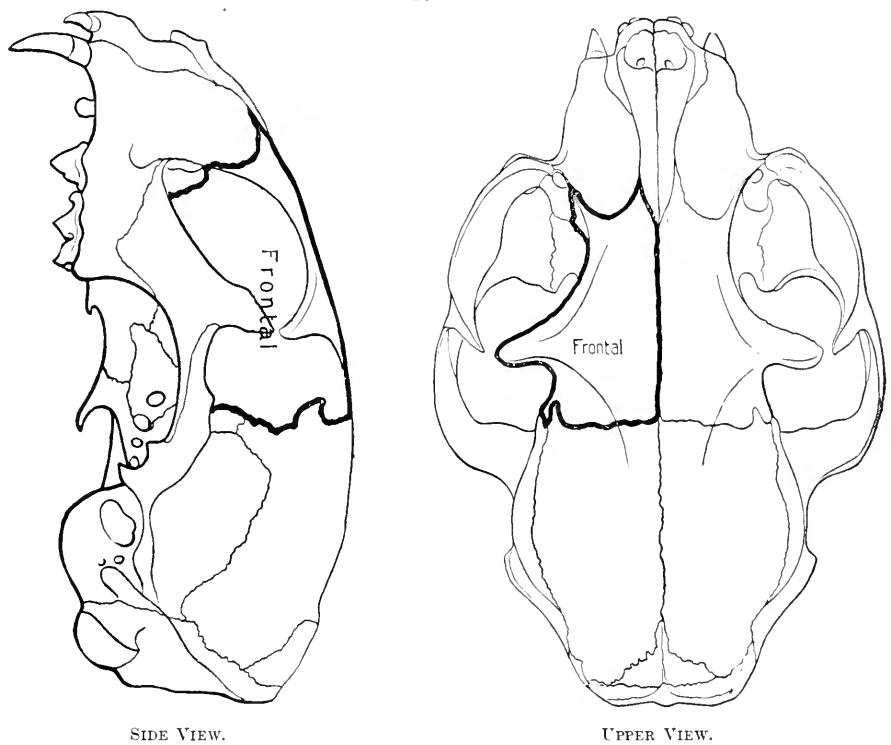
and medially across the lamina to the opening of the Vidian canal corresponds to the long Vidian groove on the inferior surface of the sphenoid of the cat. Lateral to this groove a wider depression leads to the scaphoid fossa and lodges part of the Eustachian tube. The outer end of the spheno-petrosal lamina projects dorsally and laterally and corresponds to the real posterior angle of the cat's alisphenoid, while the human **sphenoidal angle**, which is lateral to the foramen spinosum and is often produced ventrally in an **angular spine**, corresponds to the roughened elevation in the cat's alisphenoid which lies just behind the foramen ovale and marks the anterior attachment of the ectotympanic. The posterior margin of the great wing joins the petrous of the temporal only by its outer parts, leaving between its inner part, the petrous, and the basisphenoid a vacuity filled in the recent state by a plate of cartilage which is pierced by the carotid artery. This opening is the **middle lacerated foramen**, so called to distinguish it from the sphenoidal fissure, sometimes termed the anterior lacerated foramen, and from the jugular foramen, sometimes termed the posterior lacerated foramen. It is rudimentary in the cat, and limited to a small opening between the notch medial to the lingula and the dorsal of the two anterior projections of the ectotympanic. The human angular spine is often marked on the medial side by a groove for the chorda tympani nerve.

### THE FRONTAL BONES.

**General Description.**—The paired unsymmetrical frontal bones form the anterior end of the cranium (Fig. 198). They limit the cranial cavity in front as the occipital limits it behind, and present between them an oblong foramen which would lead into the cavities in the face were it not closed by the cribriform plate of the ethmoid (Figs. 199, 200). The frontals form the greater part of the inner and upper walls of the orbits, wherein are lodged the eyes, a large part of the upper and outer walls of the nasal cavities, and a small part of the temporal fossæ (Fig. 200). In old skulls the two frontals are sometimes united, and the interfrontal part of the sagittal suture known as the metopic suture may be entirely obliterated; in skulls of ordinary age, however, the two bones can be easily separated.

Each frontal consists of two well-marked parts: a smooth, slightly convex, **horizontal plate**, covered by the scalp and forming the fore-

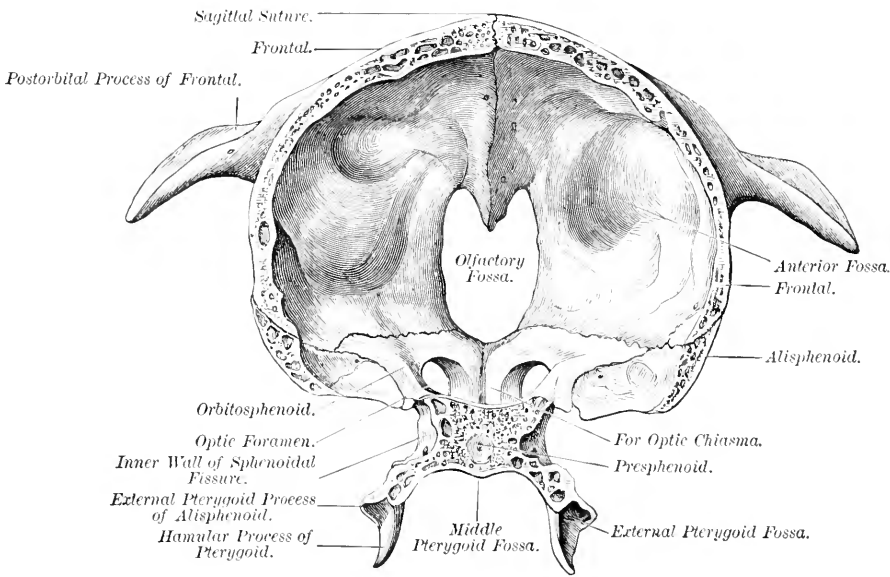
FIG. 198.



POSITION OF LEFT FRONTAL BONE.

head; and a **vertical plate**, which is deeply impressed behind on the inside, to lodge a part of the brain, and deeply impressed in front on

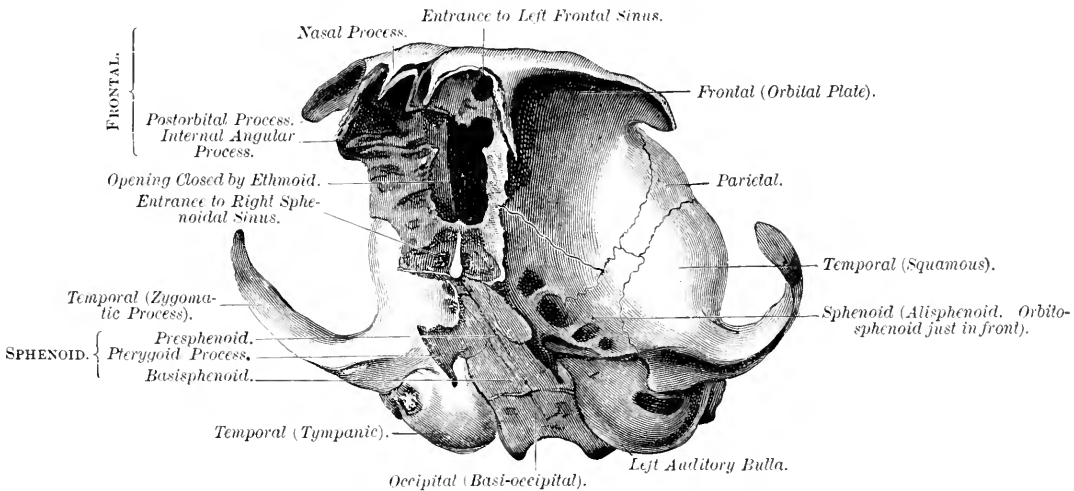
FIG. 199.



TRANSVERSE VERTICAL SECTION OF THE SKULL THROUGH THE SPHENOIDAL FISSURE, SEEN FROM BEHIND.

the outside, to receive the eye. From the inner edge of the horizontal plate there descends a second, much smaller, vertical plate, called the **median plate**, which forms, behind, the inner wall of the cavity which lies in the centre of the frontal bone, known as the **frontal sinus**, and in front articulates with the nasal bone and the upper border of the median plate of the ethmoid. The median plate thus contributes one-half of the upper part of the median partition which divides the nasal cavity into two halves. The inner flat surface of the median plate joins the corresponding part of the opposite frontal bone.

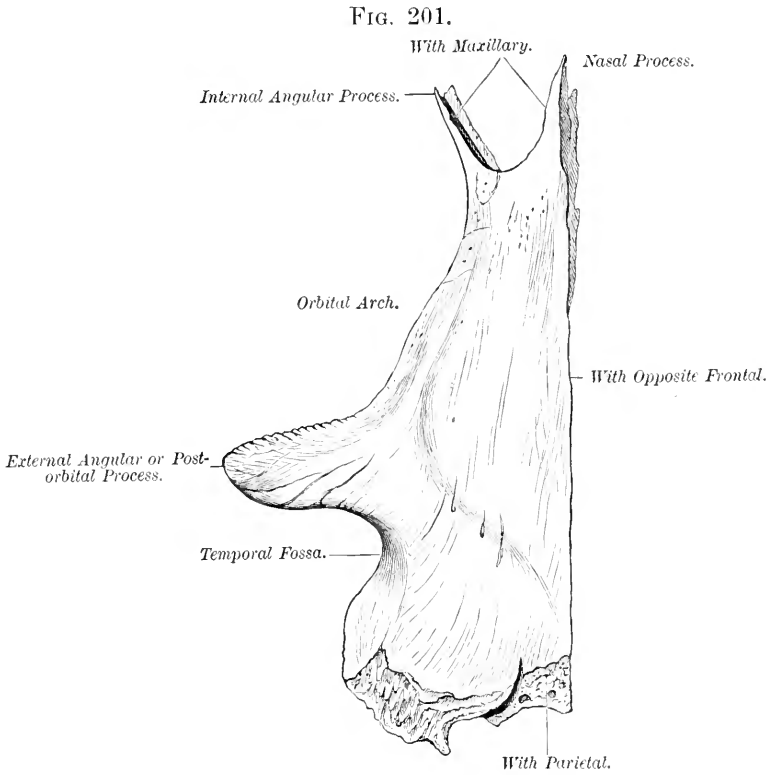
FIG. 200.



THE CRANIUM VIEWED FROM IN FRONT, BELOW, AND THE LEFT SIDE. (Natural size.)

The **Horizontal Plate** presents a **superior** or **outer surface** (Fig. 201) which is somewhat triangular, pointed in front and wider behind. For most of its extent it is smooth and flat, but in front and behind and at the outer side it slopes downward. The inner border is straight, except at its anterior end, which turns slightly outward and as the inner border of the pointed **nasal process** joins the upper part of the outer border of the nasal bone. The other side of the process is continued backward and outward into the anterior border of the frontal, which is deeply emarginate, so as to receive the ascending process of the maxillary, and ends in a distinct **internal angular process**, from the side of which the lateral border, or orbital arch, begins. The lateral border divides the horizontal from the vertical or orbital plate, and forms the upper rim of the orbital opening. It is sharp, arched, and ends behind in the anterior border of the **external angular** or

postorbital process. Behind this process the superior surface is often separated from the lateral surface by a curved **temporal line**, which begins at the root of the postorbital process and curves upward, backward, and inward to meet the end of the curved line on the parietal at a point on the coronal suture known as the **stepha'nion**;<sup>1</sup> sometimes,



however, the lateral border becomes indistinct and the superior surface rounds down into the vertical portion of the bone. The posterior border is jagged, somewhat bevelled at the expense of the superior surface, and passes at the side into the posterior border of the vertical plate. It articulates with the anterior border of the parietal bone.

The **Vertical Plate** presents an external and an internal surface.

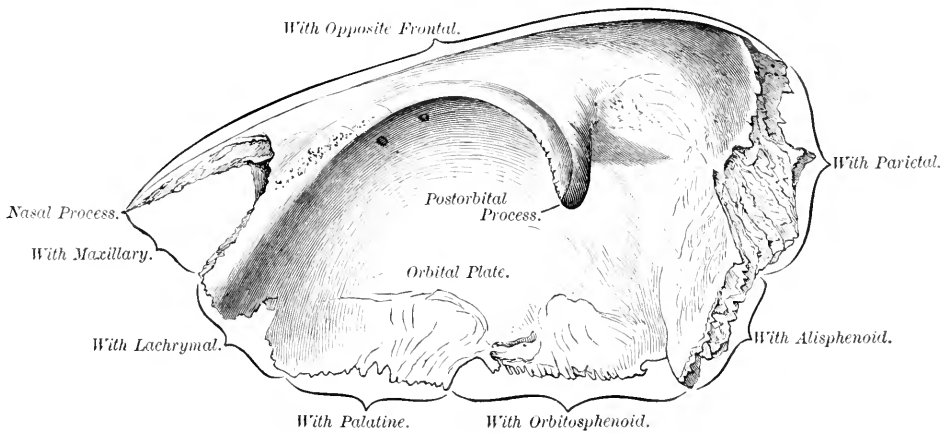
The **external surface** (Fig. 202) is divided into two parts, a large anterior concave portion, entering into the formation of the inner wall of the orbit, and a small posterior convex portion, contributing to the temporal fossa.

The **orbital portion or plate** is dome-shaped. The lower border is

<sup>1</sup> From (Gr.) *stephanos*, a crown.

nearly straight, and jagged; it is articulated with the following bones: in front, where it is directed somewhat upward for a short distance, with the upper border of the lachrymal, and to a varying degree with the os planum of the lateral ethmoid when present; then with the ethmoidal process of the palatine; and for the posterior half with the edge of the orbitosphenoid. Somewhat behind the middle of this border is a notch converted by the orbitosphenoid into a canal which enters the cranial cavity at the lower end of the articulation of the cribriform plate of the ethmoid; in many specimens in advance of this opening

FIG. 202.



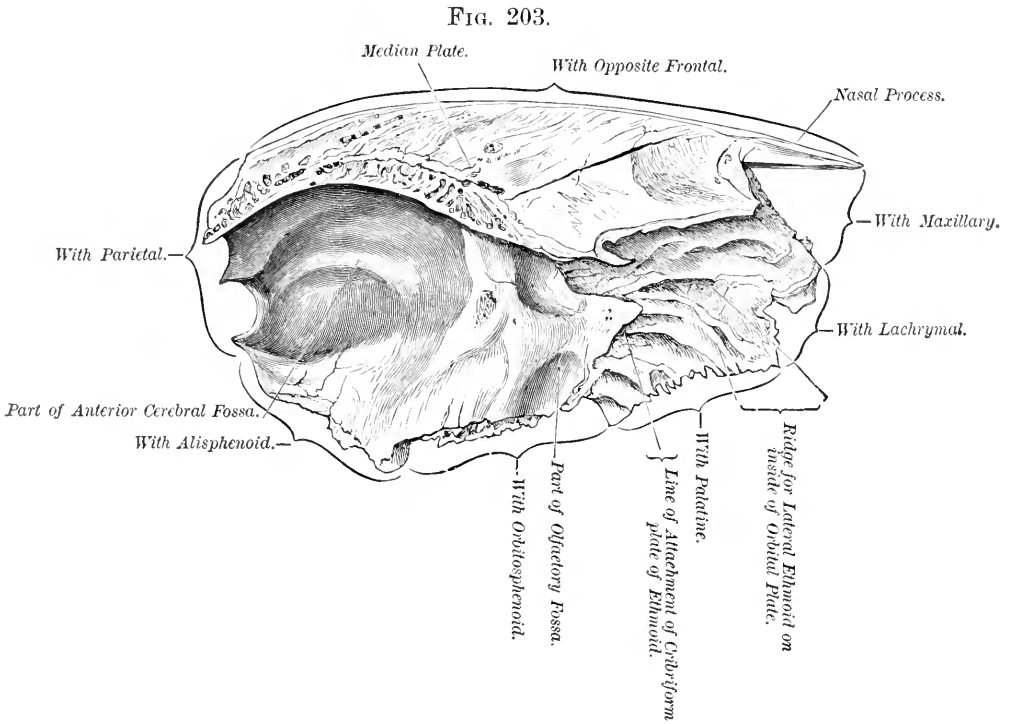
LEFT FRONTAL BONE, OUTER ASPECT.

is a small foramen which enters the nasal cavity. The anterior and upper borders of the external surface are formed by the sharp edges of the internal angular process, the orbital arch, and the postorbital process. The posterior border is not well defined. It curves downward and backward from the postorbital process to the posterior lower angle of the bone, separates the orbital and temporal surfaces, and is continuous with the infratemporal crest on the alisphenoid.

The **postorbital process** is a pyramidal prolongation of the supra-orbital ridge. Its anterior surface faces downward and forward, is smooth and concave, and is continuous with the upper part of the orbital plate. Its superior surface is flat and convex, faces upward and backward, and passes into the depressed portion of the superior surface of the horizontal plate. The posterior surface is rounded, faces downward and backward, and gives origin to fibres of the temporal muscle. Near its base is an inconstant foramen leading into the cancellous tissue.

The **temporal portion** of the vertical plate is triangular, the apex pointing downward and backward. It passes without a break into the orbital plate in front and into the horizontal plate above. It is convex in both directions, and behind is largely encroached upon by the overlapping anterior border of the parietal.

The **internal surface** of the vertical plate of the frontal (Fig. 203) is divided, like the external surface, into two parts, but with the difference that in this case the anterior part is small and the posterior is large. The two parts are separated from each other by a crooked,



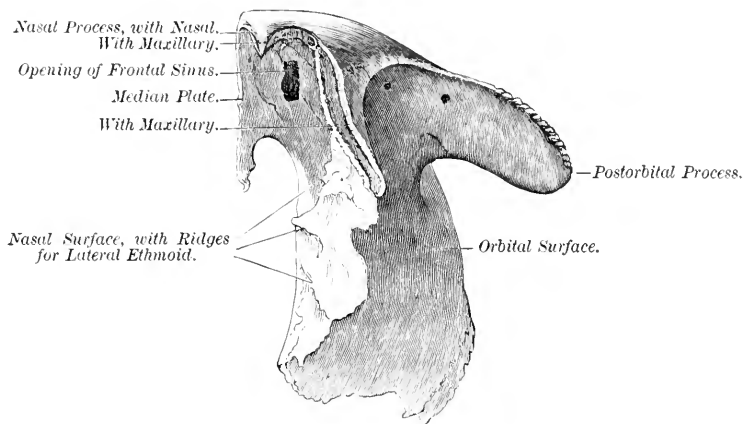
LEFT FRONTAL BONE, INNER SURFACE.

jagged line, running downward and backward, at the junction of the anterior and middle thirds. To this line is attached the edge of the cribriform plate of the ethmoid.

The **anterior part** is rudely triangular, and produced in front on the internal angular process. It passes, above, into the outer surface of that upper part of the nasal cavity which is sometimes called the external frontal sinus. It is nearly flat, and faces slightly downward and forward as well as inward. It is marked by **five ridges** beginning at the cribriform line and running obliquely downward and forward. The

upper and longest ridge indicates the lower limit of the external frontal sinus. To these lines are attached the bony partitions between

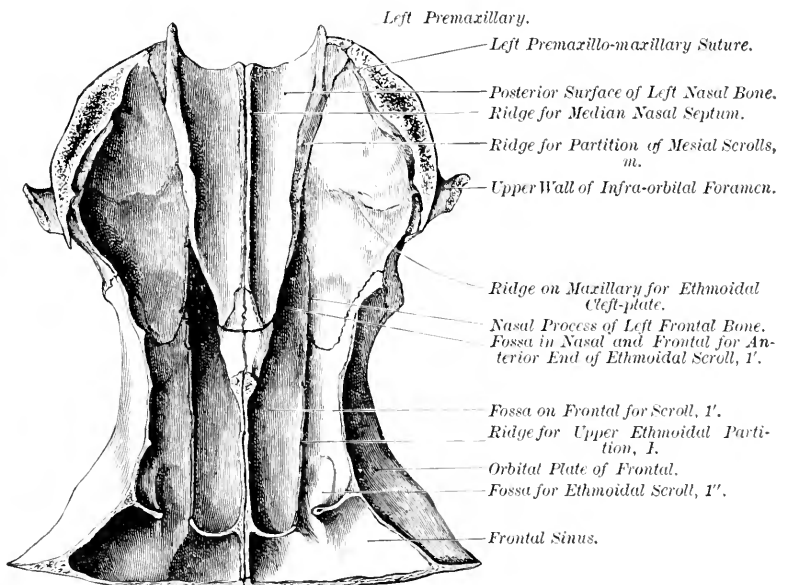
FIG. 204.



LEFT FRONTAL BONE, ANTERIOR VIEW.

the scroll-like portion of the lateral ethmoid. This surface forms the upper posterior part of the outer wall of the nasal cavity. Its anterior border articulates above the internal angular process with the maxillary,

FIG. 205.



ROOF AND PART OF ANTERIOR WALL OF NASAL CHAMBER; ETHMOID REMOVED.

and below it with the lachrymal, the os planum, the palatine, and the orbitosphenoid.

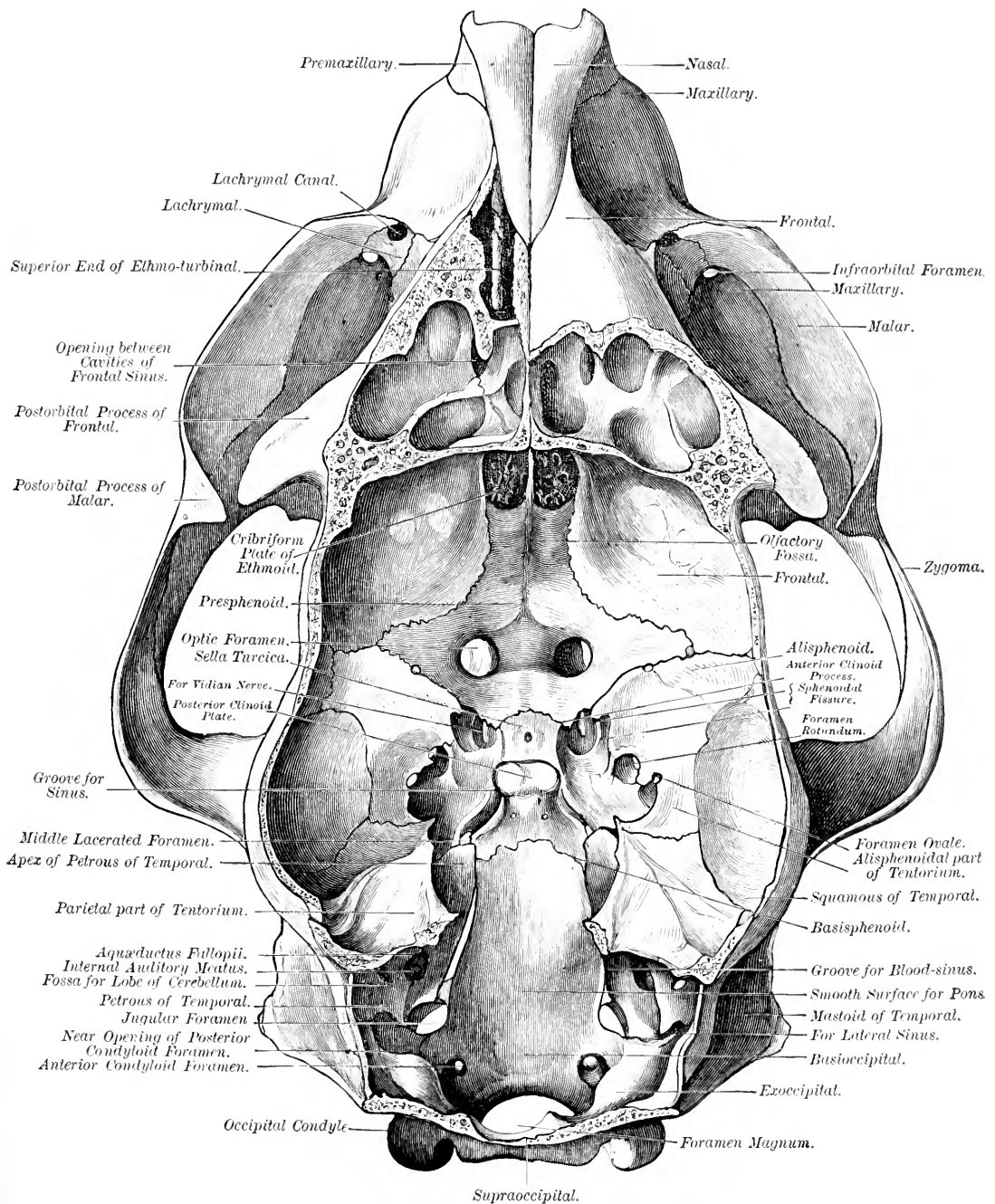
The **external frontal sinus** (Figs. 204, 205) is about as wide as high, and deeper than wide. It forms the upper chamber of the nose. It is open in front and below, but when the bone is in place the anterior opening is filled by the nasal and maxillary bones. Its inner wall is the outer surface of the median plate, and the outer wall the upper part of the inner surface of the orbital plate. The roof (Fig. 205) is formed by the horizontal plate, prolonged in front into the nasal process. On the roof is a longitudinal ridge which is continued down the short posterior wall of the cavity. This wall is a partition which divides the external sinus from the internal sinus, and, in the outer of the two sections formed by the longitudinal ridge, is pierced by a foramen which permits more or less of the tip of the upper external scroll (1') of the lateral ethmoid to protrude into the internal sinus. The inner section on the roof receives the inner uppermost scroll (1'') of the ethmoid.

The **frontal sinus proper** (Figs. 206, 207) is a cavity contained in the upper part of the bone. It communicates with the nasal chamber by the opening just described. Its floor is formed by the orbital plate and the part of the horizontal plate over the cerebral surface which may be called the cerebral plate. Its inner wall is formed by the median plate, and its outer wall by the inner surface of the orbital and temporal plates. Its posterior wall is the cerebral plate, and its roof is the horizontal plate. It is often prolonged outward and backward into the base of the postorbital process and downward into the constricted part of the bone which separates the olfactory and anterior cerebral fossæ. Its walls are sometimes marked by ridges.

The **cerebral surface** (Figs. 199, 203, 206) occupies the greater part of the inner surface of the vertical plate of the bone. It consists of a narrow, vertical, anterior portion and a large, cup-shaped, posterior portion. The anterior portion faces inward, and is bounded in front by the cribriform line, below by a short, straight, serrated, inferior border, articulating with the orbitosphenoid. It rounds outward behind into the second portion, and is arched above by a small surface which is concave from side to side and joins the median plate. It forms the outer and upper walls of the olfactory fossa for the olfactory lobe of the brain. The larger cerebral portion is deeply concave and faces principally backward and inward, forming, with the other frontal above, with the cribriform plate of the ethmoid in front, and with the anterior sphenoid



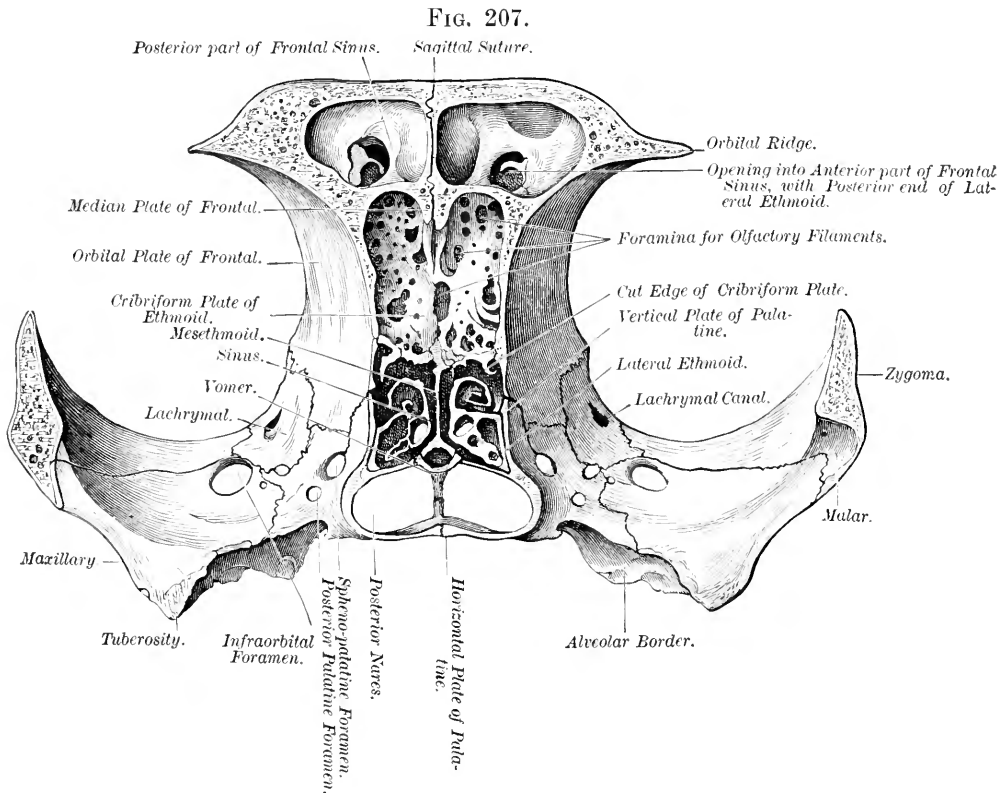
FIG. 206.



THE SKULL, CRANIAL CAVITY FROM ABOVE.

below, the anterior cerebral fossa, or a third of the cranial cavity. It is marked by several wide, shallow grooves running downward and forward, which contain convolutions of the anterior cerebral lobe of the brain.

Near its anterior border as it curves to the median plate above is a very small venous foramen. Its lower border, which is directed outward and backward, is serrated, and articulates with the orbitosphenoid. The posterior border is convex, and joins the parietal above and the



TRANSVERSE VERTICAL SECTION OF SKULL THROUGH ORBITS, SEEN FROM BEHIND.

alisphenoid lower down. Near the lower posterior angle the surface presents faint grooves which proceed upward more or less parallel with the posterior border and lodge the anterior meningeal artery. Along the straight superior border is a faint groove for the longitudinal sinus.

The general shape of the inner surface of the **median plate** is that of a razor-blade. It is flat, and roughened, especially behind, for articulation with the opposite bone. A crescentic depressed area in front marks the point of articulation with the nasal bone. It is bounded

above by the gently convex horizontal surface. The lower border begins behind at the posterior middle angle, curves downward, and, following the concavity of the upper part of the cerebral surface, becomes slightly convex where it joins the mesethmoid. The anterior border is emarginate.

**Nomenclature.**—Frontal is from *frons*, the forehead. *Os frontale* and *os frontis* are the Latin anatomical terms most generally used. The French is *le frontal*, and the German equivalent *das Stirnbein*. Old names are *os coronale*, the bone which bore the crown, *os sincipitis*, the bone of the sinciput, or forepart of the head, and *os proræ*, the prow bone, from the resemblance of the anterior end of the inverted calvarium to the prow of a ship.

**Determination.**—When the frontal is held with the external flattened surface uppermost and the broader posterior end toward the student, the postorbital process is on the side to which the bone belongs.

**Articulation.**—The frontal articulates with the nasal, the maxillary, the lachrymal, the ethmoid, the palatine, the orbitosphenoid, the alisphenoid, the parietal, and the opposite frontal.

**Muscular Attachments.**—The temporal is attached to the outer surface of the horizontal and vertical plates below the temporal line and to the posterior surface of the postorbital process. To the orbital rim is fastened a strong fascia, in which are inserted parts of the occipito-frontalis and the orbicularis palpebrarum.

#### VARIATIONS IN THE FRONTAL BONES.

##### VARIATIONS IN SIZE.

The following measurements were taken upon a large number of frontal bones; when several specimens were identical in size only one was noted in the table.

The maximum length is the length along the metopic suture from the posterior angle of the horizontal plate to the tip of the nasal spine.

The maximum width is the distance from the most convex part of the temporal surface to the plane of the medial surface of the median plate.

The maximum height is the distance, taken at a right angle, from the superior surface of the horizontal plate to the lowest point of the vertical plate.

## RIGHT FRONTAL BONE.

Maximum Length.	Maximum Width.	Maximum Height.	Maximum Length.	Maximum Width.	Maximum Height.
35	21	15	41	23	16
36	22	16	41	23	17
37	22	17	41	24	20
37.5	22.5	16	41	21	14
37.5	30.5	16	41.5	21	15
38	23	15.5	41.5	23	18
38	22	17	42	23	17
38	24	18	42	23.5	18
38	22	16	42	24	17
39	21	17	42	25	17
39	22	16	42	22	17
39	23	19	42	23	16
39	22	19	42	24.5	17
39	20	15	43	24	17
39	22.5	16	43	24	19
39.5	23	18	43	25.5	19
40	24	15	43	25	17.5
40	22	17	43.5	22	18
40	24.5	18	43.5	23	20
40	22	18	44	27.5	17
40	21	16	44	23	17
40	24	17	44.5	25	19
40.5	24	18.5	45	24	18
40.5	23	16	45	22	16
40.5	24	20	46	24	16
41	24	17	47.5	24	15
41	23.5	15	48	26	18

## LEFT FRONTAL BONE.

Maximum Length.	Maximum Width.	Maximum Height.	Maximum Length.	Maximum Width.	Maximum Height.
32	25	17	41	25	19
36	22	17.5	41	24	17
37	23	17	41	24	19
37	23	18	41	24	18
38	22	16	41.5	22	18
38	23	17	42	23	18
38	23	19.5	42	24	20
39	23	18	42	26	16
39	25	17	42	26	17
40	23	19	42	26	19
40	24	18	42.5	22.5	17
40	24	19.5	42.5	24	15
40	22	16	43.5	23	19
41	20	17	44	22.5	17
41	24.5	18	44	26	16
41	23	18	45	23	17
41	24	19.5	47	24	15

## VARIATIONS IN FORM AND DEVELOPMENT.

The frontal presents variations in the number and distribution of its foramina. In about one-fourth of the specimens examined the supraorbital ridge was pierced near the middle by a small opening into the cancellous tissue. A distinct suborbital foramen just under the orbital arch was present in two-thirds of the specimens; rarely this foramen was double. The ethmoidal foramina near the lower border of the vertical plate were usually present as a large notch and just in front of it a small foramen which emerged on the nasal surface; in some specimens, however, there were two notches, in others two foramina, in others a single notch or a single foramen, and in many no distinct notches or foramina were visible. The postorbital foramen was absent in about one-third of the specimens; in a very few instances it pierced the superior surface of the process.

The presence of a temporal line was observed in two-thirds of the bones; it was rarely entirely absent, but was usually obscurely defined. In many cases, probably about a third of all studied, the bevelling on the superior surface for the parietal was extended in a point to the root of the postorbital process. The size of the postorbital process varies greatly: in some specimens it is long and either massive or very slender, in others it is reduced to a mere tubercle.

The nasal surface of the vertical plate presents such changes as are dependent upon the variations in the lateral ethmoid, to which it furnishes lines of attachment. In the majority of the specimens studied there were six oblique ridges for the ethmoidal partitions; in a few this number was increased to seven or even eight, showing an increased complexity in the ethmoidal scrolls. In only one case was the number reduced to five.

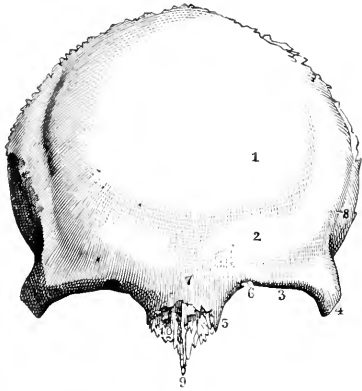
In three left frontals out of one hundred and fifty of both sides, the frontal sinus was entirely absent, and its place was occupied by firm cancellous tissue.

## HUMAN FRONTAL BONE.

When a child is about six years old the frontal bones begin to unite along the metopic suture; the adult skull therefore usually presents but a single bilaterally symmetrical frontal bone. In comparing it with the frontal of the cat, of course we need only to study one-half of it.

The most obvious characters in the human frontal are the great size and strong convexity of that portion of the horizontal plate situated behind the orbital rim, the marked reduction of the parts of the horizontal and vertical plates in front of the orbital rim, and the almost transverse direction of the orbital rim itself.

FIG. 208.



EXTERNAL VIEW OF THE FRONTAL BONE.

1, position of the frontal eminence; 2, superciliary ridge; 3, supraorbital arch; 4, 5, external and internal angular processes; 6, supraorbital notch or foramen; 7, glabella; 8, temporal ridge; 9, nasal spine.

The orbital portion of the vertical plate is small, and its direction is so changed that it faces downward and slightly forward.

The superior surface of the horizontal plate (Fig. 208) is more strongly convex at the frontal eminence, above the orbital rim. Below the eminence is a transverse depression, and beneath this an arching elevation known as the **superciliary ridge**. The union of the superciliary

ridges of the two frontals over the nasal suture produces the nasal eminence or **glabella**. Below the ridge is the sharp **supraorbital margin**, which ends laterally at the **external angular process** and medially at the **internal angular process**. At its inner part is a notch, sometimes converted into a foramen, for the supraorbital vessels. A well-marked **temporal line** curves from the external angular process to the parietal border.

The intracranial surface (Fig. 209) is strongly concave, and forms an angle in front with the orbital plate. Its medial side is grooved behind for the longitudinal sinus, but in front is elevated into a ridge continuous with the crista galli on the superior surface of the ethmoid; at the extreme anterior end a vertical groove is converted by the ethmoid into the **foramen cæcum** for a vein. The intracranial surface is marked by cerebral convolutions, by vessels, and by Pacchionian bodies.

That part which corresponds to the median plate is so far reduced that the opening to the frontal sinus is almost on the anterior surface of the bone.

The lower parts of the two rudimentary median plates are united and produced forward and downward as the **nasal spine**, above and

on each side of which are fastened the nasal bones. The nasal process of the maxillary has a small sutural attachment to the front of the internal angular process.

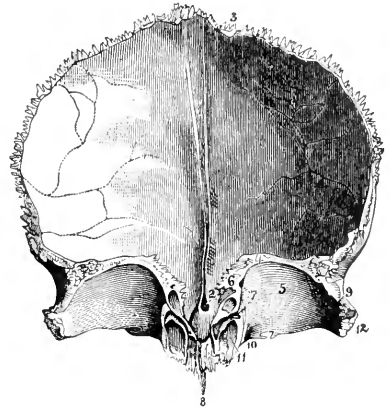
The orbital surface of the vertical plate is more deeply concave in its outer part for the reception of the lachrymal gland. Near its medial anterior corner are a tubercle and a pit for the attachment of the trochlearis or superior oblique muscle of the eyeball. Between the internal angular process and the nasal spine is the opening to the frontal sinus. Behind this opening the medial margin of the orbital plate is wide and impressed by the upper surface of the lateral ethmoid. It is crossed by two grooves which the ethmoid converts into the anterior and posterior ethmoidal foramina. The space between the medial margins of the two bones is known as the **ethmoidal notch**.

The external angular process unites with the malar, thus forming the upper part of the lateral orbital wall.

### THE ETHMOID.

**General Description.**—The Ethmoid is a cubical, bilaterally symmetrical bone which almost completely fills the nasal cavity (Fig. 210). It is without distinct processes, and consists almost entirely of a mass of thin, delicate scrolls of bone, whereby the superficial area of the wall of the nasal cavity is largely increased, inasmuch as the mucous membrane which covers the wall invests every separate scroll. In other words, every scroll is lined by the mucous membrane of the nasal cavity, and thereby contributes to this great increase of the superficial area of the nasal wall. Its posterior surface, which can be recognized as the curved sieve-like plate, forms part of the anterior wall of the cranial cavity, filling the gap left between the frontals above and at the side and the presphenoid below (Fig. 200).

FIG. 209.

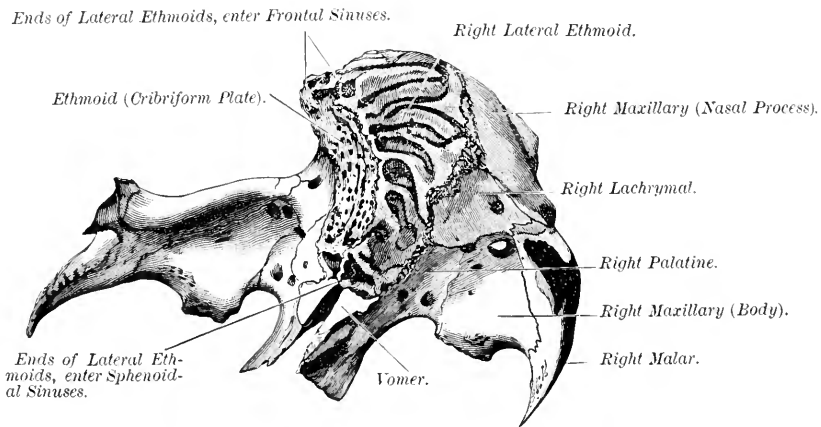


INTERNAL VIEW OF THE FRONTAL BONE.

1, groove for the longitudinal sinus, narrowing below on the frontal crest, 2, in the ethmoidal notch; 3, superior dentated border, articulating with the parietal bones; 4, posterior border of the orbital plate, 5, which joins the small wing of the sphenoid bone; 6, irregular inner border of the same plate, which covers the upper part of the ethmoidal scrolls; 7 points to the position of the ethmoidal foramina; 8, nasal spine; 9, thick rough border articulating with the great wing of the sphenoid bone; 10 refers to the black spot, which indicates the position of a fossa for the pulley of the trochlearis muscle; to its outer side is the supraorbital notch; 11, internal angular process, and entrance to the frontal sinus; 12, external angular process.

Its lateral surfaces and the posterior part of the upper surface are in close contact and more or less coalesced with the bones which form the walls of the nasal cavity,—namely, the frontals and orbitosphenoids of the cranium (Fig. 200) and the maxillaries, nasals, lachrymals, and palatines of the face (Fig. 210). A portion of the lower surface is united with the vomer. The greater part of the anterior end is free in the nasal cavity, and may be seen by looking into the anterior nasal

FIG. 210.



BONES OF THE FACE, WITH ETHMOID IN POSITION. VIEWED FROM ABOVE, BEHIND, AND THE RIGHT SIDE. (Natural size.)

aperture. Except for a small variable spot on the inner wall of the orbit, the ethmoid is not visible on the exterior of the skull. When the investing bones are removed, the ethmoid is seen to have somewhat the form of a cube, compressed, however, laterally, so that its greatest width is slightly less than its height, which in turn is one-third less than the length. It is highest at the back and lowest in front. Its greatest width is between the lower anterior angles or directly above them at the posterior end of the anterior quarter of the length.

On closer examination the ethmoid is seen to be composed of five parts :

Of these, two large similar vertical lateral masses, made up of bony cells, lie on each side of the middle line and together compose almost the entire bone; they are called the **lateral ethmoids**, or **ethmoturbinals**.

Situated between these, and almost in contact with their inner surfaces, is a thin vertical plate, known as the **mesethmoid**, or **per-**



**pendicular plate** of the ethmoid. This plate joins the frontals and nasals above and the vomer below, and with its cartilaginous forward extension divides the nasal cavity into two lateral chambers, each almost filled by the lateral ethmoid.

The lateral ethmoids and the mesethmoids are fastened together above and behind by a thin transverse **cribriform plate** which separates the nasal cavity from the cranial cavity and is pierced by numerous small holes for the transmission of the olfactory nerves.

Below and behind, the lateral ethmoids coalesce with the posterior expanded portion of the vomer. A transverse vertical section through the posterior part of the bone shows the relation of these parts. Such a section may be represented by the Roman numeral III, in which the upper transverse bar is the cribriform plate and the lower transverse bar is the vomer with its expanded wings. The lateral vertical bars represent the lateral ethmoids, and the middle vertical bar is the perpendicular plate.

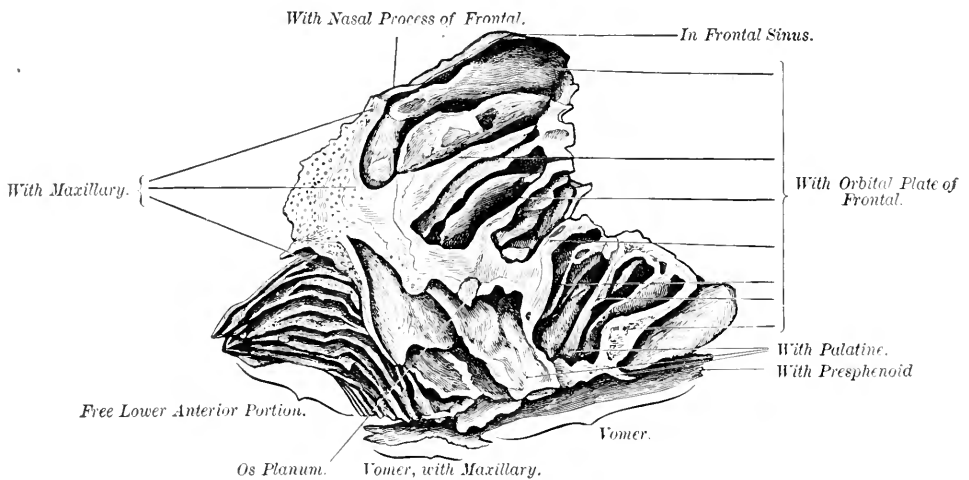
#### THE LATERAL ETHMOIDS.

Each lateral ethmoid is a mass of bony scrolls which is flattened so that its width is only half its height. Its widest point is in front and below. Its height is a third less than its greatest length. It presents large internal, or medial, and external, or lateral, surfaces; a long, narrow, rounded superior surface; a triangular lower surface more or less incised and wide in front and narrow behind; a high and narrow posterior surface; and a triangular anterior surface, the apex of the triangle being above.

The **external surface** (Fig. 211) has the outline of a distorted square, the upper angles lying in front of the lower angles. The lower border, somewhat irregular owing to the downward projecting ends of the bony scrolls, is quite straight and horizontal. Its length is about four-fifths of the entire length of the surface. Its posterior end is prolonged as the rounded end of the lower posterior scroll. The posterior border is about as long as the lower border, and meets the lower border at an angle of sixty-seven degrees, being directed forward as well as upward. It is deeply emarginate, inasmuch as it is the lateral border of the cribriform plate, which is concave from above downward. It is jagged for articulation with a curved line on the inner surface of the vertical plate of the frontal. At its upper end is the more or less prominent and rounded posterior end of the upper

outer scroll. The superior outline of the external surface of the lateral ethmoid is slightly longer than the antero-posterior length of the surface itself. It is formed behind by the upper border of the superior external and internal scrolls, in the middle by the thin longitudinal partition which separates them, and in front by the plate on the inside of the upper ends of the upper anterior scrolls. This outline is gently arcuate from behind to the anterior fifth, where it is

FIG. 211.



THE ETHMOID AND VOMER, LEFT SIDE, OUTER SURFACE.

interrupted by an abrupt step-like drop. From this point it is continued straight to the end. The upper outline is directed downward and forward at right angles to the posterior border. The anterior border is only about half as long as the superior border. It is straight, and is formed by the lower edges of the outer lower anterior scrolls. It is not parallel with the posterior border, but inclined more forward at the upper end, making approximately an angle of sixty degrees with the lower border.

The external surface is divided into a small triangular anterior third and a larger quadrilateral posterior two-thirds by a deep moderately wide *ethmoidal cleft*, which begins below, behind the anterior lower angle, and runs nearly parallel with the posterior border obliquely upward and forward and ends just before it reaches the superior border. This cleft cuts half-way through the lateral ethmoid. It is not perpendicular to the plane of the external surface, however, but slopes obliquely inward and backward in such manner that, when

the surface is viewed directly from the side, only the anterior wall of the cleft is visible, the bottom being overhung by the posterior edge. The cleft is subject to considerable variation in depth, shape, and direction. It usually is deeper above than below, and its upper end curves forward.

The large section of the external surface lying behind and above the cleft is almost square, and is about one-third higher than it is wide. Its upper third faces upward as well as outward, and the lower two-thirds face outward and slightly downward and backward. This part of the external surface consists of a series of narrow scrolls of thin bony tissue placed one above the other and running across the long axis of the surface, that is, downward and forward in the nasal chamber. The scrolls are slightly curved, the convexity facing upward. The topmost scroll is the longest, and they become successively shorter as they descend. Not all of the surface is occupied by the scrolls. Along and parallel with the posterior border of the cleft which divides this part from the anterior triangular part is a thin bony plate, which, as we shall see, represents the external expanded edge of the bar which runs upward from the lower part of the expanded scrolls, forms the posterior wall of the cleft, and gives attachment to the anterior ends of the six upper scrolls. This plate covers the anterior ends of the scrolls; it is continued backward as the external edges of

the partitions which spring from the posterior wall of the cleft, lie between and parallel with the scrolls, and end by joining the cribriform plate above and behind. The lower edge of the plate forms the lower border of the surface. The partitions, which usually number seven (Fig. 212), are wider in front than behind, and

may vary considerably in length, width, and form. The upper are the longest, and those near the middle are shorter and more curved.

FIG. 212.



LATERAL ETHMOID, EXTERNAL SURFACE. PARTS NUMBERED, LARGER SCROLLS SHADED.

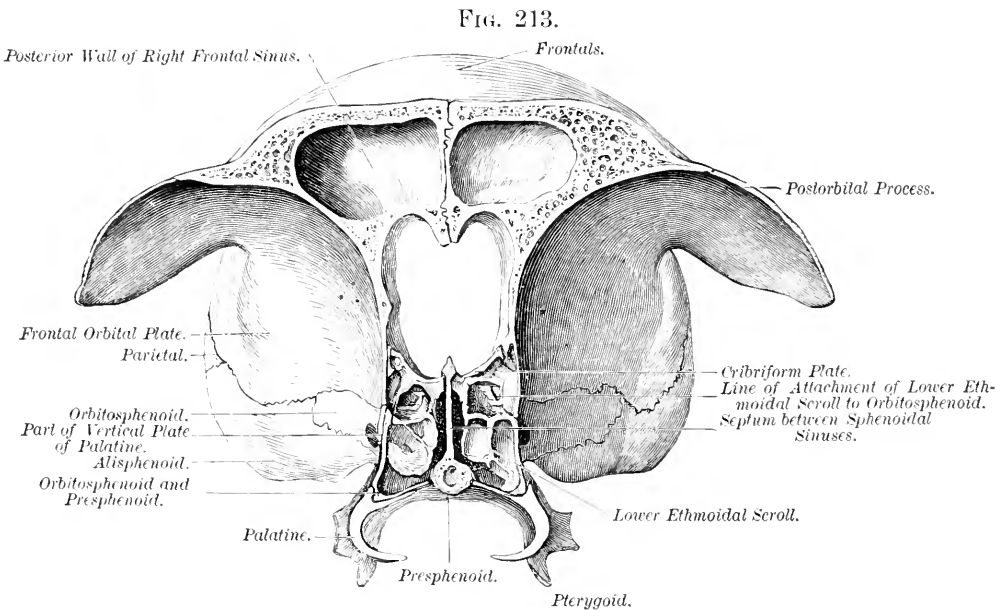
Usually two scrolls are placed between two partitions; below the lowest partition is a single more swollen scroll. The scrolls also are attached by their posterior ends to the cribriform plate. The broad posterior border of the cleft already described—namely, the border from which the edges of these partitions appear to arise—presents an upper third which is flat and square, faces upward and outward, and together with the anterior end of the first partition is more or less closely united with the upper part of the inner surface of the nasal process of the maxillary bone. At the upper anterior edge of this border is attached the upper outer end of a broad curved plate which extends downward and backward as the greater part of the anterior wall of the dividing cleft, forming a posterior shield to the small scrolls which make up the anterior triangular part of the bone. As we shall see, this **cleft plate** is a downward leaf of the curved plate which covers the top of these small scrolls. This plate in turn is part of the third scroll seen in the inner or medial surface of the lateral ethmoid (Fig. 219, m). The plane of the lower two-thirds of the plate-like posterior border of the cleft forms an angle with the plane of the upper third, facing outward and backward; at about its middle, between the anterior ends of the third and fifth partitions, is a wider portion which is flat and elevated and applied to the anterior part of the inner surface of the orbital plate of the frontal. A part of this area, usually a round or oval patch, is smooth and dense, and often appears on the inner wall of the orbit between the frontal, the lachrymal, and the palatine bone, as the **os planum** (Fig. 211). The rest of this strip, bounding the cleft behind, is depressed and concave; it is overhung above and behind by the elevated portion, and does not touch the investing lachrymal bone, nor is its lower edge in contact with the inner surface of the vertical plate of the palatine bone. The partitions lying between the scrolls are attached to corresponding ridges on the inner surface of the frontal, except the anterior ends of the first and second, which join the maxillary, and the lower ends of the sixth and seventh partitions, which with the lower border are applied to the palatine (Fig. 214).

The upper part of the seventh partition is attached to the inner wall of the sinus in the presphenoid, which contains the lowest scroll (Fig. 213).

The attachment of these partitions to the plate in which they ter-

minate anteriorly and to the cribriform plate and to the investing walls of the nasal chamber produces cavities which are sometimes called the **ethmoidal cells**. Every cavity, except as noted, contains two scrolls.

The scrolls and partitions are not independent structures, but are continuous within, the partitions being merely the outer unrolled edges of the scrolls. Although there is considerable diversity in the arrangement of these parts, it would seem that the inner edge of each



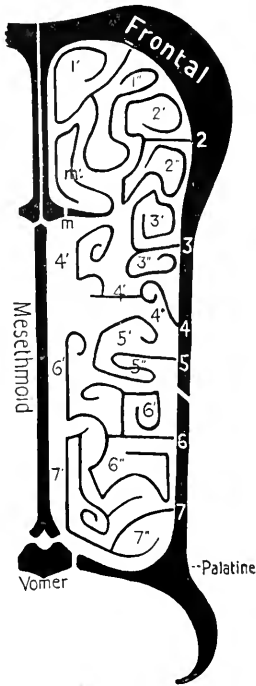
THE SKULL. TRANSVERSE SECTION JUST BEHIND POSTERIOR NARES, SEEN FROM IN FRONT.

partition splits and rolls up to form the scrolls which lie on either side of it. Many of these scrolls appear on the inner or medial surface of the lateral ethmoid, which surface they largely form, but they are considerably disturbed by pressure. The third and fourth scrolls, counting from the upper border (Fig. 214, 2', 2''), do not appear on the inner surface of the lateral ethmoid, as they rest in part on the first and second scrolls (1', 1'') and in part are covered by two additional scrolls, which are seen only on the inner surface (Fig. 219, m', m''). The fifth and sixth scrolls (Fig. 214, 3', 3'') likewise are seen only on the external surface, owing to the expansion of the seventh and eighth scrolls (4', 4'').

Notwithstanding distortion by pressure, it is possible to separate this larger posterior part of the lateral ethmoid into eight little masses, which may be detached from the posterior wall of the cleft in front and

from the cribriform plate behind. Each mass consists of a narrow plate with a scroll above and a scroll below. A transverse section of the mass may be represented diagrammatically thus,  $\begin{smallmatrix} \circ \\ \text{---} \end{smallmatrix}$ . With one

FIG. 214.



TRANSVERSE VERTICAL SECTION THROUGH HALF OF FACE.  
Three millimetres anterior to central part of cribriform plate of  
ethmoid. Cut surfaces black (somewhat diagrammatic).

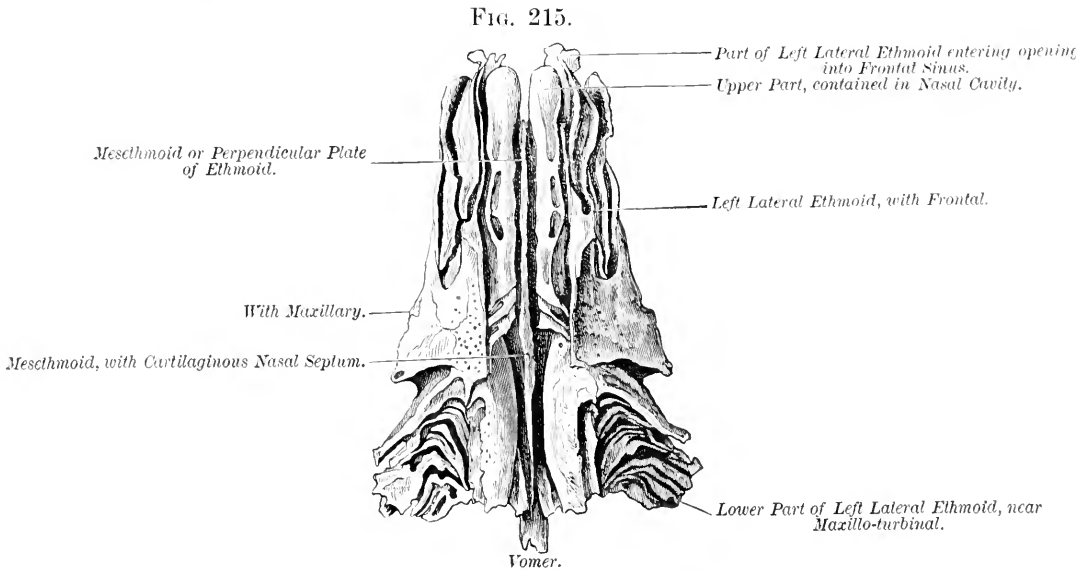
exception (Figs. 214, 219, m), no partitions appear on the inner surface of the lateral ethmoid, as that surface is for the most part not attached to the median plate of the frontal nor to the mesethmoid which it faces. The fourth pair of scrolls is expanded in front, forming first the floor of the cleft, and then, splitting up into thin plates, becomes, still further forward, the smaller part of the external surface of the lateral ethmoid. They are also seen at the anterior end of the inner surface, but, as there is no

cleft on this surface, the distinction is at first not so obvious.

The smaller part of the external surface (Figs. 211, 215) which lies anterior to the vertical cleft is triangular in outline. The shorter upper border is directed downward and forward; the lower border is directed downward and backward, and is emarginate to fit over the maxillo-turbinal; the posterior border, which is about as long as the lower border, is also directed upward and forward, but more vertically, forming nearly a right angle with the superior border. The triangle is composed of many scrolls, which differ from the posterior scrolls in being narrow, delicate, and pressed close together; they also differ in being directed upward and forward. They are attached below and behind and are free in front and above. Their upper ends curve downward.

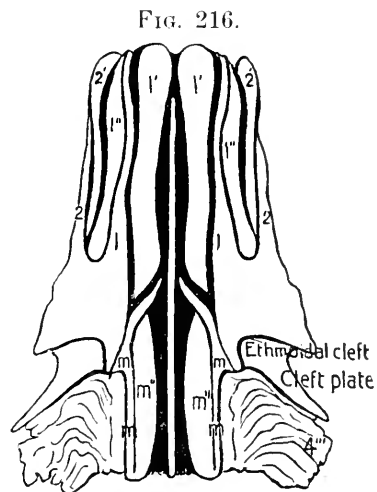
The superior surface (Fig. 215) of the lateral ethmoid is long and

narrow. For the posterior half or more it is formed by the upper rounded surface of the upper scroll (Fig. 216, 1'), and on the outside



THE ETHMOID BONE, ANTERIOR ASPECT.

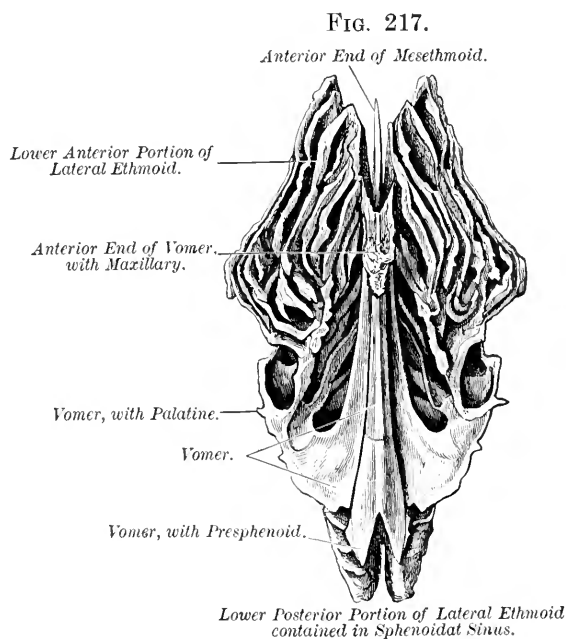
of the scroll by the sharp edge of the first partition (1), continued in front as the upper edge of the posterior border of the cleft on the external surface. The partition is fastened to a ridge on the roof of the so-called external frontal sinus which contains the scroll. Where the scroll ends in front, separated from it by the obliquely directed anterior end of the edge of the single partition on the inner surface (m), is the beginning, on a lower level, of the plate-like forward extension of the third scroll on the inner surface (m''), which forms the rest of the surface and covers the upper surface of the small anterior scrolls.



triangle is above. The inner outline is nearly vertical; the outer border is directed from above downward and outward; the lower border is pointed in the middle, encroaching on the lower surface as an elevated process, from which the delicate scrolls which form the surface seem to arise. As a whole, the surface is concave from above downward and convex from side to side, and faces downward and forward and toward the upper surface of the maxillo-turbinal.

The posterior surface of the lateral ethmoid forms one-half of the upper surface of the cribriform plate (Fig. 243).

The lower surface of the lateral ethmoid (Fig. 217) is exposed when the vomer is removed. It is triangular, wider in front than



THE ETHMOID AND VOMER, LOWER ASPECT.

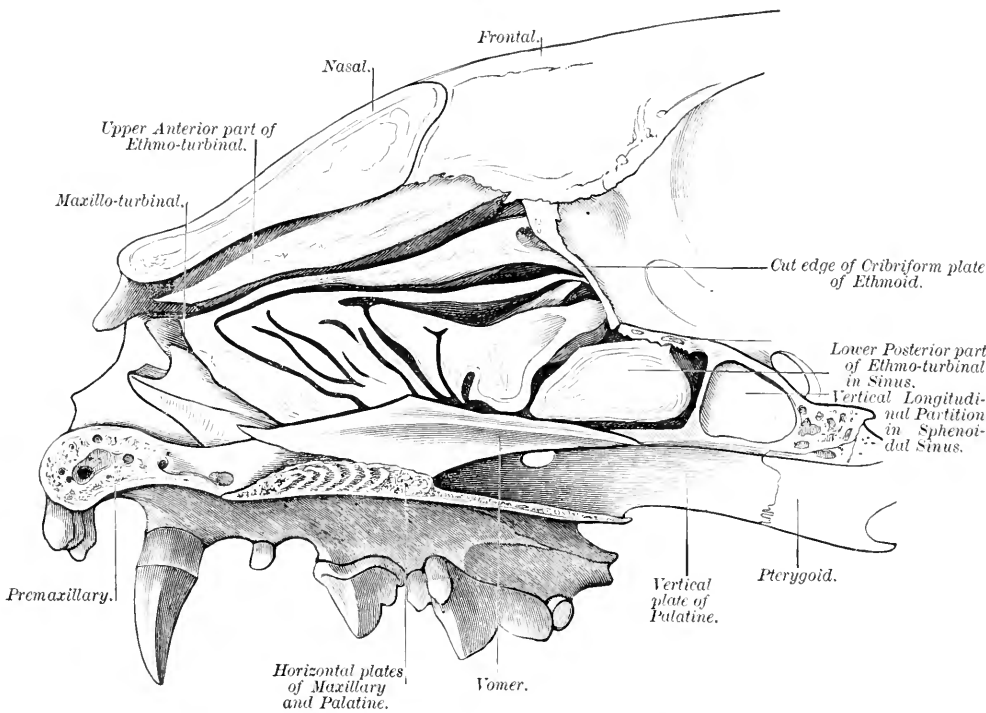
behind. The inner edge is longitudinal, and the outer edge is directed backward and inward. The posterior half of the surface is formed of the under surface of the largest lowest scroll, whereof the rounded posterior end is received into the sinus in the presphenoid. In front of the scroll and continued for a short distance along the outer border is a small flattened area which represents the lower extended portion of the seventh inner scroll. An incision visible in front and on the outside is the lower end of the cleft on the external surface. On the inside are the roots of several plates on the inner surface of the



combined tenth and eleventh and combined twelfth and thirteenth outer scrolls. The plates or folds which form the anterior end of the lateral ethmoid are joined to this area by a narrow stalk. The expanded lateral posterior part of the vomer is attached to the flatter bands along the outer borders of the inferior surface, and is overlapped by the sphenoidal processes of the palatine bones. In front of this union and on each side of the vomer spaces are left between the lower surface of the ethmoid above and the palatine plates of the maxillary and palatines which lie below and form the floor of the nasal chamber. These spaces, called the **inferior meatuses**, are canals which open anteriorly at the anterior nares. Behind the attachment of the vomer to the palatines they communicate with each other freely, and their common posterior end opens into the pharynx at the posterior nares.

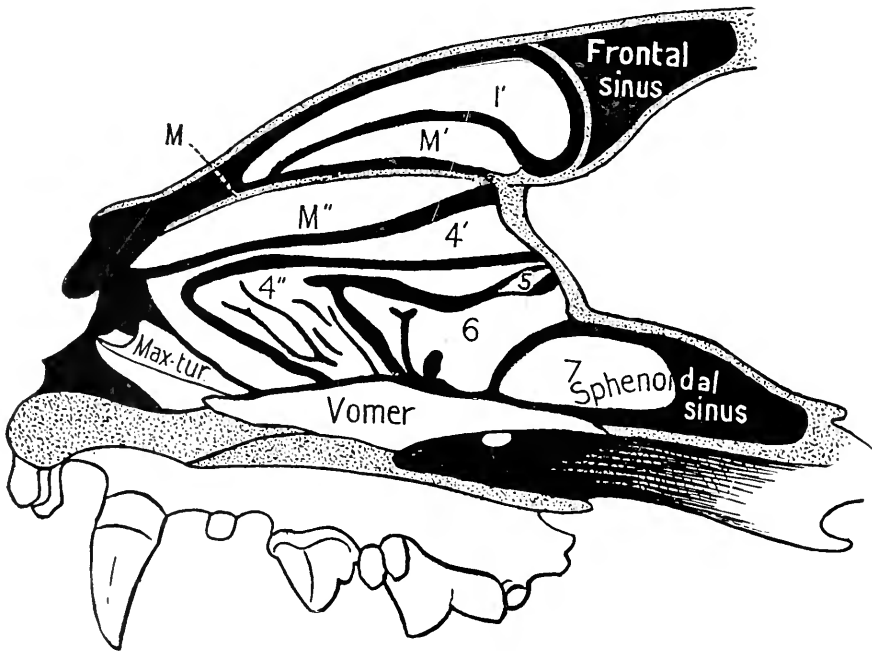
The **internal** or **medial surface** of the lateral ethmoid (Figs. 218, 219) has the same shape as the outer surface. It is much flatter, however, and not divided into two distinct parts by a vertical fissure. The scrolls which compose it are larger and simpler, because, with one exception, every one is the inner surface of two united outer scrolls. An area occupied by the third, fourth, fifth, and sixth scroll is depressed below the rest of the surface. This area is wider behind at the cribriform plate and narrower in front where it cuts through the superior border behind the anterior angle. This depression forms with the side of the mesethmoid a passage known as the **superior meatus** of the nose. There are eight scrolls on this surface. The upper one (Fig. 219, 1') is long and curved and larger behind than in front; the anterior end turns outward to join the end of the partition behind it and the next outer scroll. The second scroll (m') is shorter; its upper convex surface lies on the concave lower surface of the first scroll, and its lower straight border lies against a partition (m) which separates it from the third scroll. This partition is slightly sinuate, and forms the upper boundary of the depressed area already described; its edge is united with the lower edge of the median plate of the frontal, with the outer edge of the posterior surface of the nasal, and, for a varying extent behind, with the upper edge of the mesethmoid. Hence the two upper scrolls are in fact shut off from the rest of the nasal chamber. The third scroll (m'') is very narrow behind, then widens and maintains the same width for the rest of its extent. It runs downward and forward; for the first half or more it is concave from above

FIG. 218.



RIGHT NASAL CHAMBER, SIDE VIEW FROM WITHIN.

FIG. 219.



LONGITUDINAL VERTICAL SECTION OF NASAL CAVITY.

Showing medial surface of right lateral ethmoid, vomer, and maxillo-turbinal (white); nasal cavity, depressions in lateral ethmoid, frontal sinus, and sphenoidal sinus (black); cut surfaces of surrounding bones (dotted).

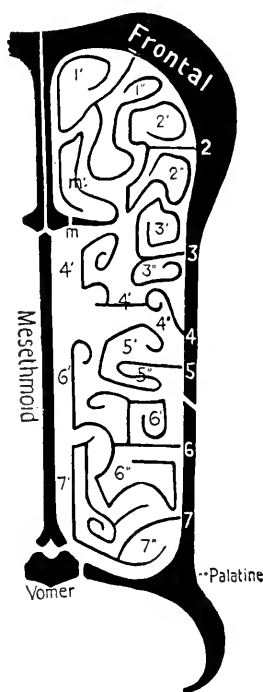
downward and faces inward; it then twists on its own axis so that the inner surface faces upward and forward and is convex in both directions. The fourth scroll (4') is nearly parallel with the third scroll, and is wider behind, but at the middle of its length it becomes very narrow; at the anterior end it bends downward and backward, and, becoming wider again, runs to the lower anterior angle, forming the anterior edge of the surface; in this region it is usually split into two or three smaller plates directed parallel with the anterior border. The fifth scroll (4'') has its shape and direction similar to the fourth, but it is narrower in its horizontal portion and large and triangular in the part bent in front down-

ward and backward; this larger part is wide above and narrow below, and is split into four delicate leaves parallel with the anterior border of the surface. The sixth scroll (5) is a very small spindle occupying a deep position between the posterior ends of the fifth and seventh. The seventh scroll (6) is flattened and triangular; the truncated apex of the triangle is on the lower border. The posterior inferior border runs downward and forward, parallel to the upper

border of the eighth scroll, and close to it. The superior border is slightly emarginate and runs straight forward or forward and slightly upward. The anterior border is parallel to the anterior border of the surface. This seventh scroll is marked by two or three curved vertical or oblique grooves, of varying length and depth, which divide it into several sections. The eighth scroll (7) is smaller, oval, and flattened.

The scrolls are attached to the cribriform plate behind. Their

FIG. 220.



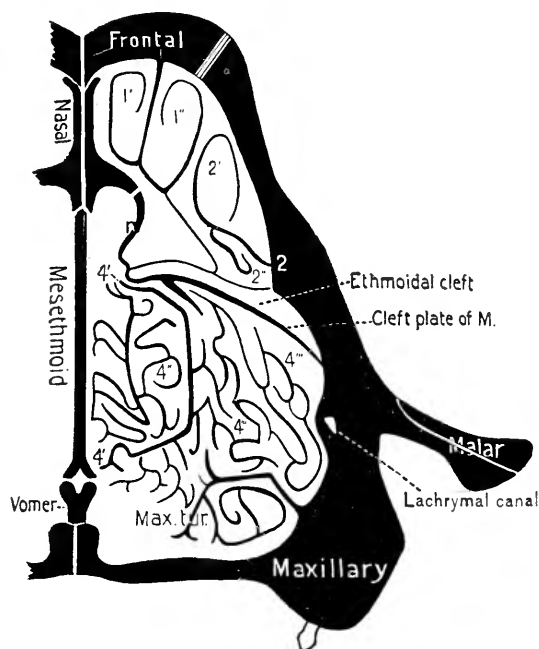
TRANSVERSE VERTICAL SECTION THROUGH HALF OF FACE.

Three millimetres anterior to central part of cribriform plate of ethmoid. Cut surfaces black (somewhat diagrammatic).

attachments are not in contact with one another, but leave slits, which are also seen on the external surface. There are no openings, however, between the second and third ( $m'$ ,  $m''$ ) nor between the fourth and fifth scrolls ( $4'$ ,  $4''$ ).

The relation between the outer and inner scrolls is as follows (Figs. 220, 221). The first inner scroll ( $1'$ ) is distinct from the first outer scroll ( $1''$ ). The first, second, third, fourth, and fifth outer scrolls ( $1''$ ,

FIG. 221.



TRANSVERSE VERTICAL SECTION THROUGH HALF OF FACE.

Just anterior to second premolar. Cut surfaces black (somewhat diagrammatic).

$2'$ ,  $2''$ ,  $3'$ ,  $3''$ ) are hidden completely on the inner surface by the second, third, and fourth inner scrolls ( $m'$ ,  $m''$ ,  $4'$ ) and the sixth and seventh outer scrolls ( $4'$ ,  $4''$ ). The sixth and seventh outer scrolls ( $4'$ ,  $4''$ ) appear on the inner surface as the fourth and fifth inner scrolls ( $4'$ ,  $4''$ ). They form also on the outer surface the mass of small anterior scrolls (Fig. 222,  $4'''$ ). The sixth inner scroll (Fig. 219, 5) comprises the eighth and ninth outer scrolls ( $5'$ ,  $5''$ ). The seventh inner scroll (Fig. 219, 6) comprises the tenth and eleventh outer scrolls ( $6'$ ,  $6''$ ). The eighth inner scroll (Fig. 219, 7) comprises the twelfth and thirteenth outer scrolls ( $7'$ ,  $7''$ ).

Each lateral ethmoid may be divided into eight pieces by cutting the attachments of the scrolls to the cribriform behind and to the plate which forms the posterior wall of the ethmoidal cleft in front.

The first and superior piece of the lateral ethmoid is a relatively large mass, oblong in shape, gently bowed upward, and slightly larger at the anterior end. Its outer side (Fig. 223) exhibits the median longitudinal partition (1), with a scroll above ( $1'$ ) and a scroll

below (1''). The lower surface, also seen on the outer aspect, is deeply concave, and receives the upper part of the second piece (Fig. 220, scroll 2').

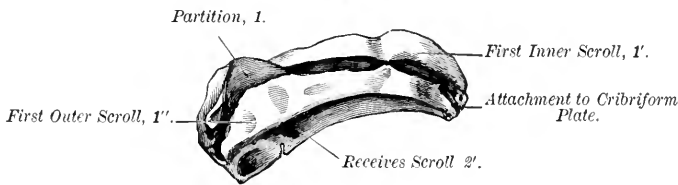
The inner surface (Fig. 224) is divided into two parts by a raised curved line extending from near the upper anterior almost to the lower posterior angle. The superior posterior triangle is swollen, and appears on the inner aspect as the first scroll (1'). The lower anterior triangle is depressed, especially in front, and fits over the second inner scroll, m', the upper part of the mesial piece (Figs. 220, 228).

FIG. 222.



LATERAL ETHMOID, EXTERNAL SURFACE. PARTS NUMBERED, LARGER SCROLLS SHADED.

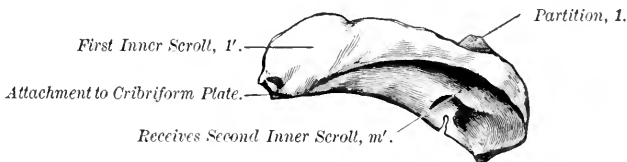
FIG. 223.



FIRST PIECE OF LATERAL ETHMOID, OUTER ASPECT.

The second piece resembles the first in general shape, but is smaller and the posterior end is narrower. Its outer surface (Fig. 225) is formed by the median partition, 2, with the scroll 2' above

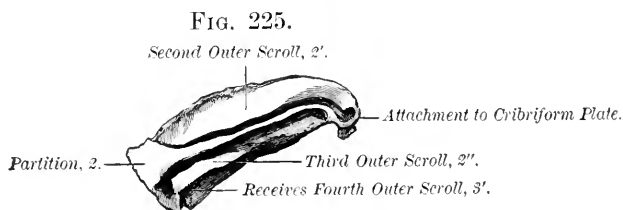
FIG. 224.



FIRST PIECE OF LATERAL ETHMOID, INNER SURFACE.

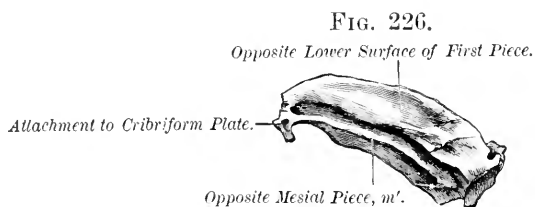
and the scroll 2'' below. Its concave inferior surface fits over the fourth outer scroll, the inner and upper part of the third piece (Figs. 220, 229, scroll 3').

When the second piece is seen from the inside (Fig. 226), the longitudinally bowed, slightly transversely concave upper surface is also



SECOND PIECE OF LATERAL ETHMOID, OUTER ASPECT.

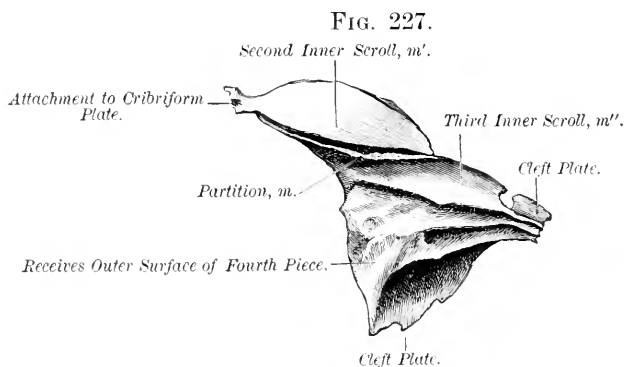
visible; below this is the inner surface proper, which is marked by a wide longitudinal median furrow. The upper surface and the inner surface down to the lower edge of this furrow are received into the



SECOND PIECE OF LATERAL ETHMOID, INNER SURFACE.

excavated lower surface of the first piece. The lower flattened part of the inner surface is opposite the lower part of the outer surface of the mesial piece (Figs. 220, 228, m').

The mesial piece (designated by m, the other pieces being numbered) is visible on the inner aspect, where it forms the second and

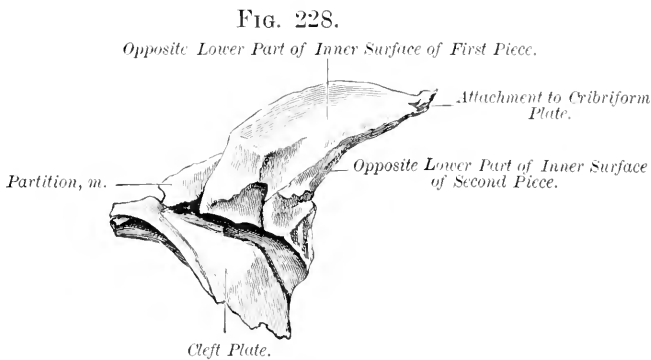


MESIAL PIECE OF LATERAL ETHMOID, INNER ASPECT.

third inner scrolls (Fig. 219, m' and m'') and appears on the outer surface only as the thin, curved cleft plate which forms the upper part

of the anterior wall of the oblique cleft which divides this surface into two parts (Fig. 222). The inner aspect of the piece (Fig. 227) is rudely triangular; it exhibits, above, the oval scroll  $m'$ , then the oblique edge of the partition  $m$ , then a depressed area  $m''$ , as already described (p. 299), limited below by a sinuous, elevated line. Only this much of the surface is visible on the inner aspect of the lateral ethmoid. Below this elevated line is a triangular lower area which fits over the depressed middle part of the outer surface of the fourth piece. Below this area, on another and external plane, is seen the strongly concave inner surface of the cleft plate. (Compare Fig. 221.)

The outer surface of the mesial piece (Fig. 228) consists of two parts: an upper, sickle-shaped body and a lower, curved cleft plate,



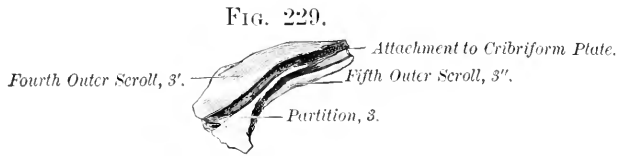
MESIAL PIECE OF LATERAL ETHMOID, OUTER ASPECT.

standing outward at right angles to it (Fig. 221). The upper portion is for the most part flattened; near the upper anterior end are a prominence and a depression which follow a depression and a prominence on the inner surface of the first piece (scroll  $1'$ ); a still lower depression, with a line continued upward and backward from its upper edge close to the lower border, marks the area opposite the upper part of the inner side of the second piece ( $2'$ ). All this part of the mesial piece is separated from the cleft plate by a deep excavation which forms the upper half of the bottom of the ethmoidal cleft. The outer edge of the cleft plate is attached to an oblique ridge on the inner surface of the maxillary bone, extending down to the lachrymal opening.

The third piece (Fig. 229) forms the fourth and fifth outer scrolls ( $3'$ ,  $3''$ ); it is much smaller than the second piece, and more flattened from side to side on the outer surface. Both scrolls are distinct; the

upper is the larger. The anterior end of the lower scroll runs under the partition (3).

The inner surface (Fig. 230), as a whole, is convex in both directions, and is applied to the upper posterior part of the fourth piece



THIRD PIECE OF LATERAL ETHMOID, OUTER ASPECT.

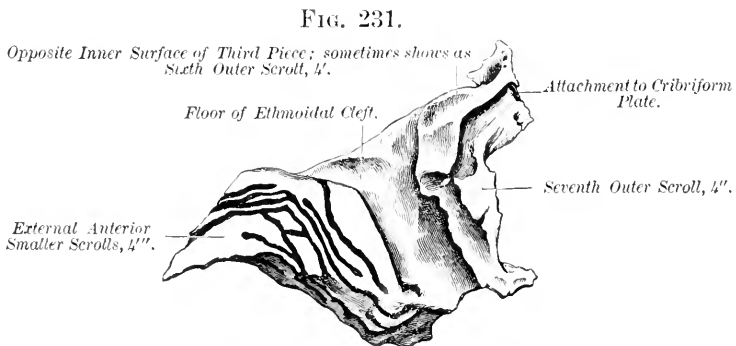
(Fig. 220, 4'). The bowed superior surface is opposite the concave lower surface of the second piece.

The fourth piece may be considered as forming the axis of the lateral ethmoid, supporting on each side, but particularly on the outer



THIRD PIECE OF LATERAL ETHMOID, INNER SURFACE.

side, the other smaller pieces, and expanding in front to produce the external and internal masses of more delicate scrolls (Fig. 221). Only the posterior part of its median partition (4) and a variable amount of the root of the lower scroll (4'') appear on the posterior quadrate



FOURTH PIECE OF LATERAL ETHMOID, OUTER ASPECT.

part of the outer surface of the lateral ethmoid (Figs. 222, 231); but the strip bordering the ethmoid cleft behind may be regarded as an



expansion externally of the partition, and the delicate scrolls anterior to the cleft (4'') may be regarded as its true termination. On the inside this piece forms the more complex fourth and fifth inner scrolls.

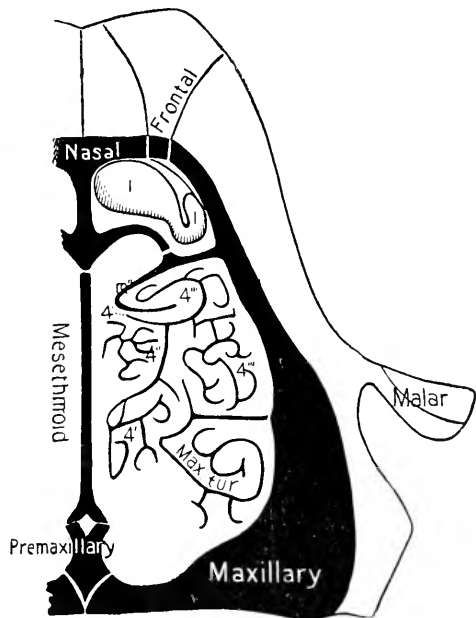
When the surrounding pieces are all removed the outer surface (Fig. 231) of the fourth piece is seen to be divided into three parts: the anterior part is the external of the two masses of scrolls attached to the front end of the partition; the middle part is the partition itself, forming the true floor of the ethmoidal cleft; and the posterior part bears, above, a small curved scroll (4'), the surface of which is applied to the inner surface of the third piece (3); below this scroll is the edge of the partition expanding vertically and outward, in front, for attachment to the anterior end of the other outer pieces. At the posterior lower angle is a portion of the lower scroll (4'').

When viewed from above there are seen, beginning at the posterior end, the posterior part of a scroll (4'), the sharp edge of the partition, and in front, on each side, the group of small scrolls. The inner group is numbered 4', 4'', and the outer group is numbered 4''' (Fig. 232).

The inner surface (Fig. 233) is made up of the inner surfaces of the fourth and fifth inner scrolls, as already described; but in the triangle left between the upper and the lower part of the fifth scroll are two excavated areas, whereof the anterior triangular area accommodates the outer surface of the sixth piece, and the posterior area accommodates the upper surface of the seventh piece.

The fifth piece appears on the outer surface of the lateral ethmoid

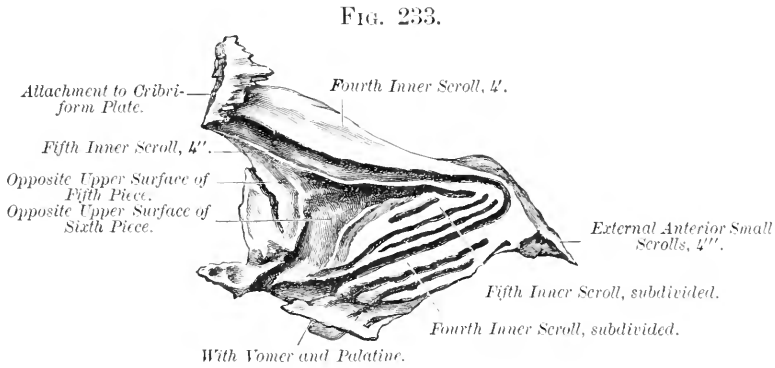
FIG. 232.



TRANSVERSE VERTICAL SECTION THROUGH HALF OF FACE.

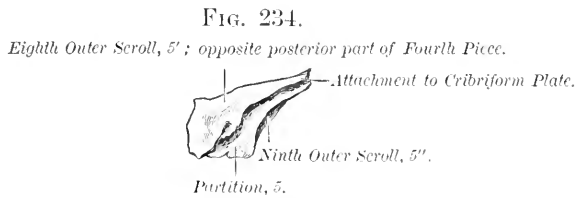
Five millimetres anterior to infraorbital foramen. Cut surfaces black. (Somewhat diagrammatic.)

(Fig. 222) as the eighth and ninth scrolls, and on the inner aspect (Fig. 219) it is seen in the interval between the posterior roots of the fifth (4'') and seventh (6) scrolls. It is a small triangular piece, and



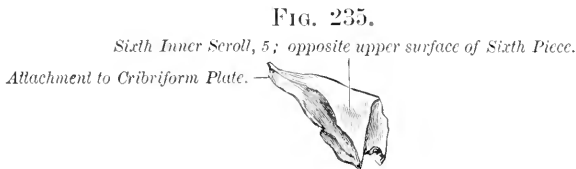
FOURTH PIECE OF LATERAL ETHMOID, INNER ASPECT.

shows on its outer side (Fig. 234) the usual three parts, but the upper scroll (5') is but slightly rolled, and is expanded at the anterior end so as to form with the narrow superior surface a convex area, which is



FIFTH PIECE OF LATERAL ETHMOID, OUTER ASPECT.

received into a corresponding concave area in the posterior part of the inner surface of the fourth piece (4''). The partition (5) curves downward and covers much of the lower scroll (5'').



FIFTH PIECE OF LATERAL ETHMOID, INNER SURFACE.

The inner surface (Fig. 235), which is also the lower surface, is triangular and entire, and fits over the upper surface of the upper scroll (6') of the sixth piece (Fig. 237).

The sixth piece is present on the outer surface (Fig. 222) as the

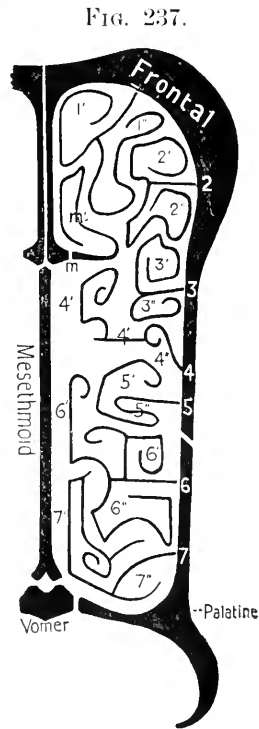
tenth and eleventh scrolls counting from the upper border, or as the third and fourth scrolls counting from the lower border; on the inner



surface (Fig. 219) it is the large, triangular, subdivided seventh scroll (6) from the superior border. When it is removed and examined on the outer surface (Fig. 236) it is apparent that there are three scrolls, two above the partition and one below (Fig. 237). The two separated by the partition are small and similar, but the uppermost one is prolonged forward, and its lower surface is cut into secondary scrolls. On the posterior part of the inner surface (Fig. 238) is a deep excavation which fits over the outer, upper part of the last or seventh piece (scroll 7').

The seventh or lowest piece is of more

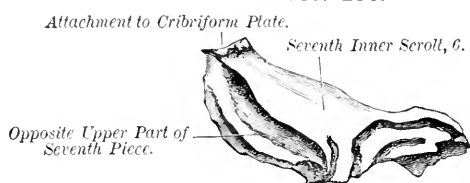
regular form, showing on the outer aspect of the ethmoid (Fig. 239) the lowest two scrolls and their dividing partition, and on the inner aspect (Fig. 240) the single, large scroll. The posterior end of this scroll fits into the sphenoidal sinus; the posterior part of the partition is attached to an oblique ridge on its outer wall (Fig. 185).



TRANSVERSE VERTICAL SECTION THROUGH HALF OF FACE.

Three millimetres anterior to central part of cribriform plate of ethmoid. Cut surfaces black. (Somewhat diagrammatic.)

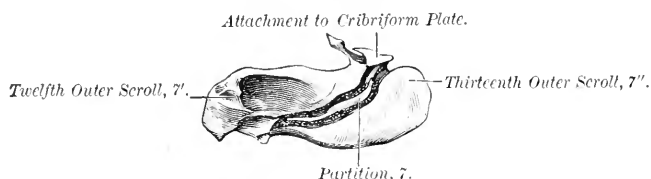
FIG. 238.



SIXTH PIECE OF LATERAL ETHMOID, INNER SURFACE.

The above description may be regarded as that of the usual form and arrangement of these pieces, but they are subject to variations,

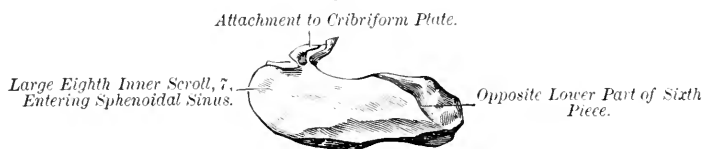
FIG. 239.



SEVENTH PIECE OF LATERAL ETHMOID, OUTER SURFACE.

especially in the extent to which the outer edges of the partitions are expanded for attachment to the walls of the nasal chambers. In some

FIG. 240.



SEVENTH PIECE OF LATERAL ETHMOID, INNER SURFACE.

cases so great is this expansion that the scrolls are scarcely visible on the external surface.

#### THE MESETHMOID.

The mesethmoid is a thin and square sheet, placed vertically and longitudinally between the lateral ethmoids (Fig. 242) and fastened by its emarginate posterior edge to the anterior surface of the cribriform plate (Fig. 241). It is nearly as long, but not as high, as the lateral ethmoids, leaving exposed the two inner upper scrolls, which, however, are separated by the contiguous median plates of the frontals extending downward.

The straight superior border, which is directed downward in front, is attached behind to the lower edge of these frontal plates, and in

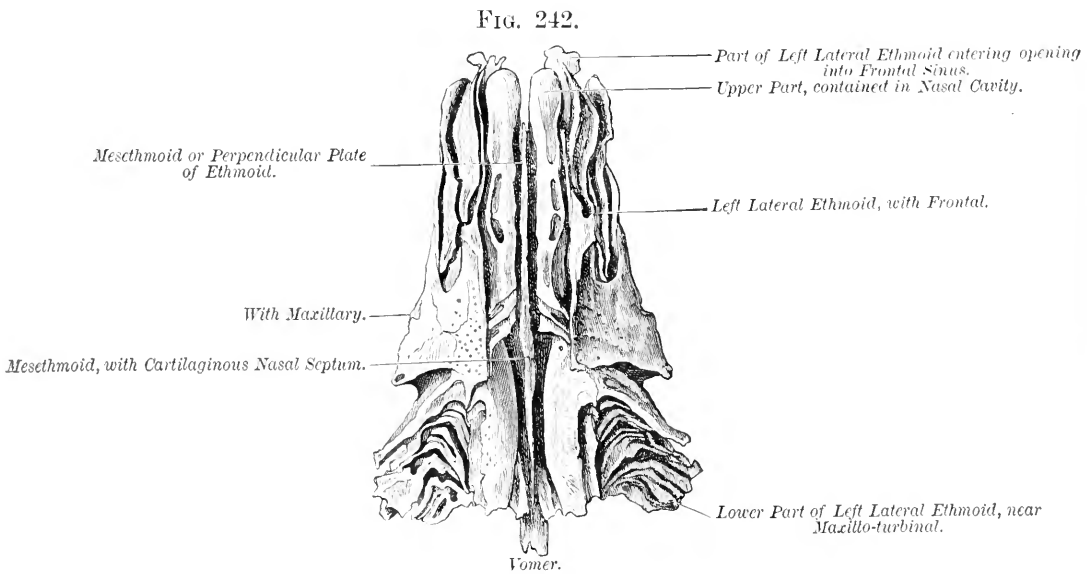
*Cut Edge of Tentorium. Middle Fossa.*



front to the posterior half of the lower edges of the inner, or median, surfaces of the nasal bones.

The short **anterior border** makes an obtuse angle with the superior border, being directed downward and forward; it then turns downward and backward so as to pass to the inferior border without forming a distinct angle. To the anterior border is attached the posterior end of the cartilaginous nasal septum.

The **inferior border** is for the most part straight, and truncate or rounder behind, leaving a small triangle between the mesethmoid, the vomer, and the presphenoid, which in the natural state is filled by a triangular, vertical plate of cartilage. In front, the inferior border



THE ETHMOID BONE, ANTERIOR ASPECT.

becomes the anterior border. The anterior and inferior borders are subject to considerable variation, dependent on the degree of extension backward of the cartilaginous septum.

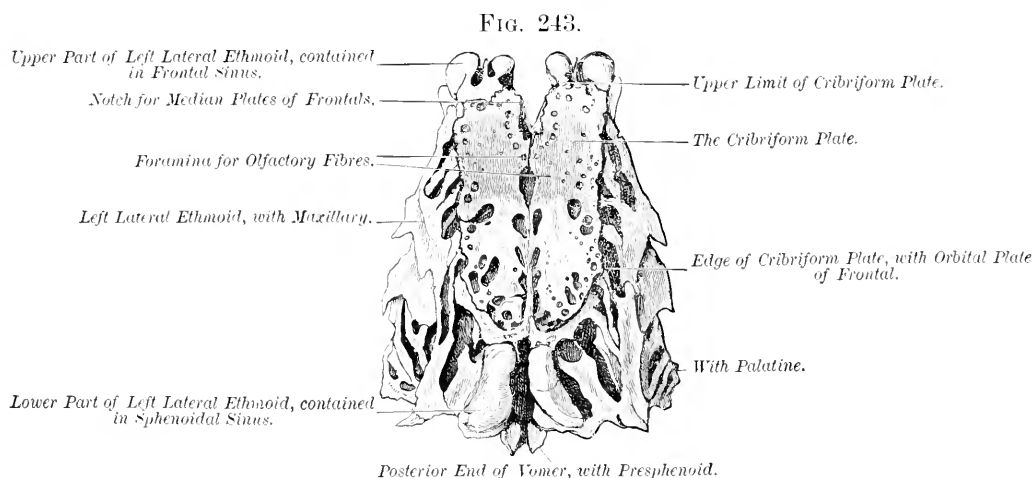
The inferior border is split into two edges by a longitudinal fissure; the edges articulate with the ridges on each side of the median groove on the upper surface of the vomer, leaving a channel between the mesethmoid and the vomer which is filled with cartilage.

#### THE CRIBRIFORM PLATE.

The cribriform plate of the ethmoid is a thin quadrilateral plate situated in the middle line at the upper back part of the bone, where

it binds together the mesethmoid and the two lateral ethmoids by their posterior ends. The greatest length equals the length of the anterior border of the lateral ethmoid, and is twice as great as the greatest width, which is slightly greater above than below. Its long axis in a median line (Fig. 241), drawn between the upper and lower borders, is not vertical to the lower surface of the whole ethmoid, but is so directed that from below the cribriform plate slopes obliquely upward and forward. On both sides of the median line it is symmetrical. It is not flat, but bent sharply across the middle in such manner that, while the lower half is directed from the middle downward and backward, the upper half is directed upward and backward. The cribriform plate is extremely thin; it consists only of posterior and anterior surfaces enclosed within upper, lower, and lateral borders.

The posterior surface (Fig. 243) enters into the formation of the



THE ETHMOID BONE, CRANIAL ASPECT.

anterior wall of the cranial cavity. Its dimensions and directions have been just given; it is slightly concave transversely, especially above. It is split above in the middle line, and the split extends down through the superior third and receives the joined median plates of the frontals. The surface, therefore, appears to separate above into two diverging horns; the tip of each horn is rounded and overhung by the posterior ends of the two upper scrolls. Below this split the median line is depressed for a distance representing approximately its middle third. In the furrow are two parallel rows of well-marked foramina, separated by a straight bar, which repre-

sents the line of attachment to the anterior surface of the posterior edge of the mesethmoid and to which is attached the falx cerebri of the dura mater. This bar becomes an elevated ridge in the lower third of the surface, and divides below to form the prominent and sharp biarcuate lower border and then ascends on each side to form the lower part of each lateral border. The lower border and these upward lateral extensions are united with the anterior end of the upper surface of the presphenoid. The lower scrolls of the lateral ethmoid, which project upward behind the lower border, are received into the sinuses of the presphenoid. The outer or lateral borders of this surface are nearer the middle line below than they are above. They are irregular and jagged, and form with the inner wall of the frontal, to which they are attached, foramina of varying size and position. The posterior surface of the cribriform plate is pierced by many **small foramina**, also seen, of course, on the anterior surface. Their arrangement on each side of the median line is, as a rule, symmetrical, although this symmetry may vary in different specimens. In the lower third they are larger and more numerous; in the upper two-thirds the large foramina are near the margins and the middle line, and leave an intermediate elongated area either pierced by few foramina or entirely solid. This area is narrowed at the middle by several large foramina near the external margin.

The **anterior surface** of the cribriform plate has the form and dimension of the posterior surface, but is convex from above downward and convex from side to side above, and nearly flat below. To the lower two-thirds of the middle line is attached the mesethmoid. On each side of this attachment is a row of large foramina. The first foramen is particularly large, and at this point a notch in the posterior edge of the mesethmoid forms a foramen of communication between the two nasal chambers. At the margins of this surface the posterior ends of the scrolls of the lateral ethmoid are attached at inconspicuous points which give no indications of the complicated convolution which they assume further forward.

**Nomenclature.**—The name ethmoid, from the Greek for a sieve, and *eides*, like, was given to this bone because of the many perforations in the horizontal plate. The ancients believed it to be a sieve through which humors from the brain were drained away. The French use *l'ethmoïde*, the Germans, *das Siebbein*. Among other names are *os ethmoidale*, *os ethmoideum*, *os cribrosum*, and *os spongiosum*.



**Articulations.**—The ethmoid articulates with the presphenoid, the orbitosphenoid, the frontal, the palatine, the maxillary, the nasal, and the vomer; it sometimes joins the lachrymal and the maxillo-turbinal.

#### VARIATIONS IN THE ETHMOID BONE.

##### VARIATIONS IN SIZE.

The following measurements were taken of twenty-five ethmoid bones:

The maximum vertical height at right angles to the lower margin of the lateral surface.

The maximum length measured parallel to the lower margin.

The maximum transverse width.

Maximum Height.	Maximum Length.	Maximum Width.	Maximum Height.	Maximum Length.	Maximum Width.
32	40	25	25	34	23
30	37	25	25	34	23
29	34	24	25	34	22
28	37	21	25	32	18
28	37	19	25	29	23
28	35	19	24	33	20
27	33	19	24	32	18
27	30	18	23	34	18
26	35	21	23	32	22
25	38	22	22	33	21
25	37	24	22	30	18.5
25	35	22	20	30	18
25	35	20			

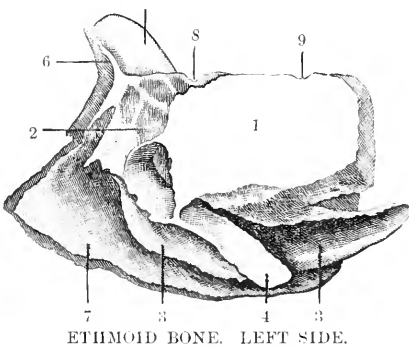
#### HUMAN ETHMOID BONE.

The human ethmoid comprises the same parts as the ethmoid of the cat,—namely, the cribriform plate, the perpendicular plate, or mesethmoid, and the two lateral ethmoids, or ethmo-turbinals, but the increase in the size of the brain and the consequent increase in the size of the anterior end of the cranial cavity have led to changes which modify materially many important details. The cribriform plate is relatively narrower, and its intracranial surface is elevated at the anterior end into a strong median crest, the *crista galli*,<sup>1</sup> with expanded basal alar processes. To its nasal surface in the middle line is fastened the edge of the mesethmoid. It will be noticed that the

<sup>1</sup> A cock's comb.

cribriform plate is almost horizontal, and does not slope from behind upward and forward as it does in the cat. There is reason to believe that this change of position is the result of the pressure of the overlying anterior lobes of the cerebrum. As a result also of this pressure some of the scrolls which form the lateral ethmoid are so bowed laterally from the middle line that their roofs show on each side of the cribriform plate, where they articulate with the depression around the ethmoidal notch of the frontal bone. It is in the lateral ethmoid itself, however, that the effect of this pressure is most apparent. If we compare the lateral ethmoid of man with that of the cat, we cannot but recognize that the horizontal position of the cribriform plate has been secured at the expense of all the upper long scrolls, by practically cutting off that part which in the cat lies dorsal to a line drawn from the posterior end of the cribriform plate to the lower end of scrolls 1 and 1'. Bearing this in mind, if we examine the human ethmo-turbinal its structure can be readily understood. In the first place, we notice that the external surface (Fig. 244) is greatly modi-

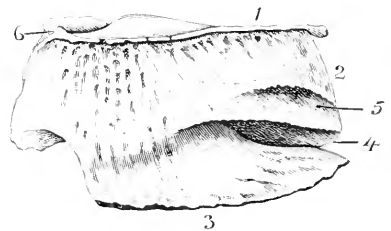
FIG. 244.



ETHMOID BONE. LEFT SIDE.

1, orbital plate; 2, anterior ethmoidal sinuses; 3, middle turbinate bone; 4, uncinate process; 5, crista galli; 6, alar process; 7, mesethmoid; 8, 9, position of the ethmoidal foramina.

FIG. 245.



RIGHT LATERAL ETHMOID. INNER ASPECT.

1, cribriform plate; 2, superior turbinate bone; 3, middle turbinate bone; 4, superior meatus; 5, a shorter meatus occasionally present; 6, part of the foramen cecum.

fied by the overgrowth of the os planum, or orbital plate, which conceals the outer surface of many of the scrolls. In front of it are seen the ethmoidal cleft and the cleft plate terminating below in a prominent *uncinate*<sup>1</sup> process, which joins the maxillo-turbinal or inferior turbinate bone.

The medial surface of the human lateral ethmoid (Fig. 245) is divided into two parts by a deep fissure extending from the posterior

<sup>1</sup> From *uncus*, a hook.

border upward and forward beyond the middle. The lower triangular part is a single scroll, the concave side of which shows on the external surface as the continuation backward of the ethmoid cleft. This scroll is called the **middle turbinated bone**; the cleft above it on the medial surface is known as the **superior meatus** of the nasal cavity, and the concavity on the lateral surface forms with the adjacent maxillo-turbinal, or inferior turbinated bone, the **middle meatus**. Hence it corresponds to the smaller scrolls anterior to the ethmoidal cleft (4', 4'', 4''') in the cat's ethmoid, and the superior meatus corresponds to the depressed area at the posterior part of the medial surface over scrolls 4', 4'', and 5 (Fig. 219).

The upper part of the medial surface, the so-called **superior turbinated bone**, in man is often deeply incised behind by a shorter longitudinal fissure just in front of the spheno-turbinal. This corresponds in the cat to the medial fissure anterior to the single large inner scroll, 7.

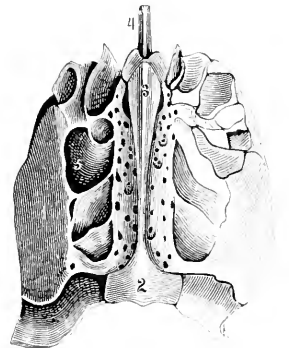
If the **cleft plate** be cut off close to the root, it will be observed that it is attached to a flat plate which forms the part of the medial surface above the anterior end of the middle turbinated bone; this plate may be recognized as a modified **mesial scroll** articulating by its thin free edge with the nasal bone.

The lateral surface of the root of the cleft plate bears ridges which are completed into **lachrymal cells** by the overlying lachrymal bone.

At the anterior end of the superior surface of the lateral ethmoid (Fig. 246) are three cells which lead down into the cleft. The first ends blindly above and corresponds to the cavity of scroll 1; the second and, sometimes, the third open above into the frontal sinus, its cavity forming the **infundibulum**, which corresponds with the cavity of scroll 1".

By carefully cutting away the *os planum* and the roof of the lateral ethmoid behind the ethmoidal cleft, the remaining partitions become visible, and the scrolls are seen to be simple irregular cavities. The posterior scroll or pair of scrolls, the

FIG. 246.



ETHMOID BONE. UPPER ASPECT.

1, orbital plate of the lateral ethmoid; 2, posterior imperforate extremity of the cribriform plate; 3, crista galli, on each side the olfactory fossa with foramina of the cribriform plate, and, in advance, the alar processes; 4, anterior extremity of the mesoethmoid; 5, ethmoidal scrolls, or sinuses.

spheno-turbinal, has lost its relations with the ethmoid and is permanently attached to the sphenoid as part of the anterior wall of its body. A large cavity in front of the superior incision on the medial surface, which runs obliquely forward and inward, may correspond with the large scroll numbered 6 on the medial surface of the cat's ethmoid. All these modified scrolls are grouped about a central partition which runs forward and joins the anterior end of the middle turbinated bone, the posterior wall of the ethmoidal cleft, and the lower ends of the infundibular scrolls; hence it may be regarded as equivalent to the partition of the large fourth piece in the lateral ethmoid of the cat.

## CHAPTER V

## THE FACE

THE part of the skull which lies beneath and in front of the cranial cavity, and hence does not surround the brain, forms the bony face (Fig. 247).

FIG. 247.



THE FACE.

*A*, side view of the skull, bones of the face black. *B*, diagrammatic transverse section, showing relations of the nasal cavity, *N*; the orbital cavities, *O*; and the mouth, *M*.

It is made up of sixteen bones, arranged in two groups.

(1) Above are two lateral masses, popularly called the upper jaws, which are immovably united with the cranium. They comprise the following fifteen bones, which constitute the anterior part of the walls of the nasal cavity and expand laterally to enclose partially the orbital cavities.

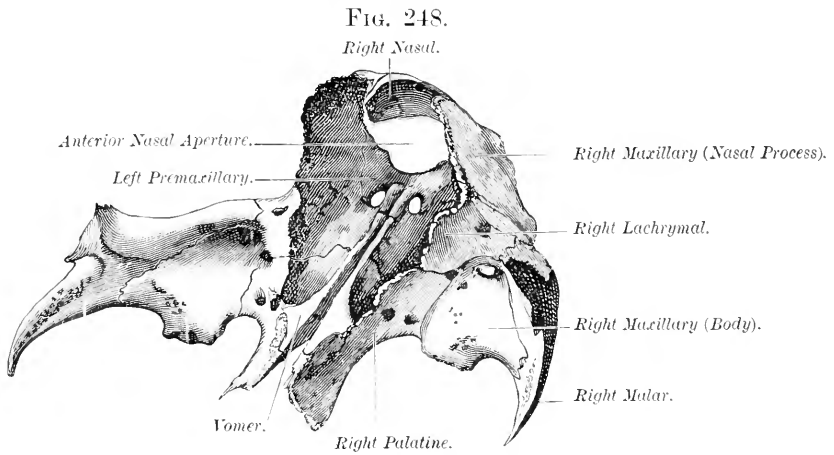
	Nasal.	Nasal.	
	Premaxillary.	Premaxillary.	
	Maxillary.	Maxillary.	
Malar.	Lachrymal.	Lachrymal.	Malar.
	Palatine.	Palatine.	
	Maxillo-Turbinal.	Maxillo-Turbinal.	
	Vomer.		

(2) Below are the two lower jaws, united to form the single mandible, which is movably fastened to the cranium and, with the lower part of the upper jaws, forms the framework of the mouth.

To the face proper may be added the eleven slender rods forming

the hyoid arch, which is suspended from the cranium and supports the larynx and the root of the tongue.

The immovable part of the face (Fig. 248) is formed principally by the paired palatine, maxillary, and premaxillary bones, each of



which sends a process upward to form a part of the wall of the nasal cavity, and a process inward to form a part of the horizontal partition between the nasal cavity and the mouth.

The paired nasal bones close in the nasal cavity in front; the lacrymals contribute a small part of the nasal-orbital wall; each convoluted maxillo-turbinal projects from the inner surface of the maxillary into the nasal cavity, and the malars form the outer boundaries of the orbits and join the temporal bones of the cranium to complete the zygomatic arches.

The only unpaired bone of the face, the vomer, is continuous with the base of the cranium; it is attached behind to the presphenoid and in front to the floor of the nasal cavity, which is thus below the level of the cranial base and permits the nasal chambers to open behind under the sphenoid bone.

### THE PALATINE BONES.

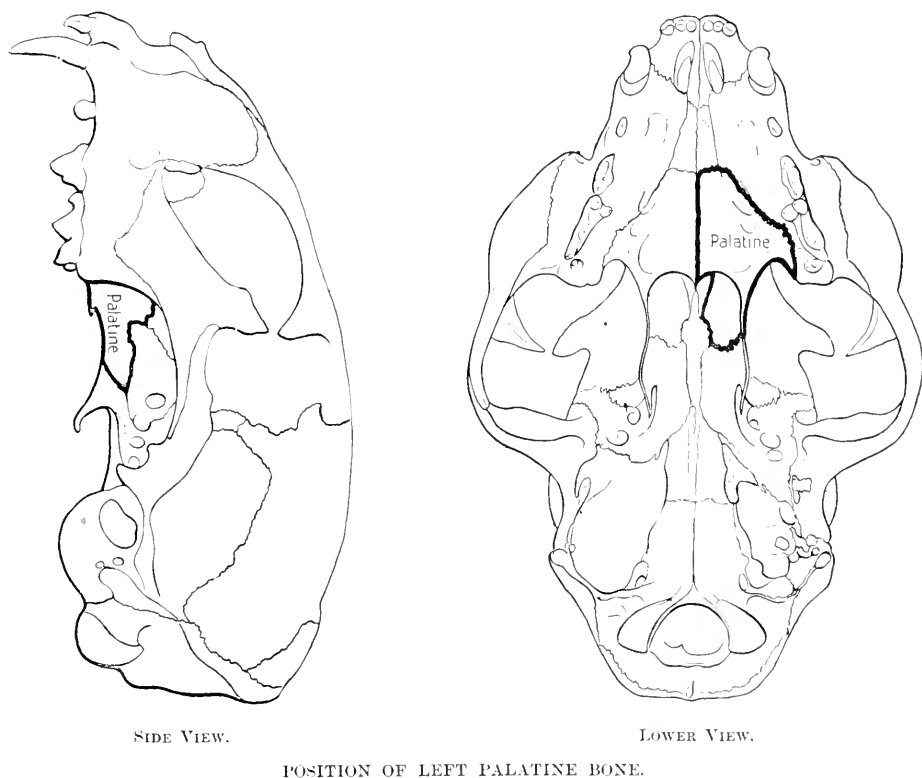
**General Description.**—The Palatines are thin, irregular bones, which form the middle lower part of the inner walls of the orbits, and, joining each other in the middle line below, complete the posterior portion of the roof of the mouth (Fig. 249). Each bone consists of

two thin plates,—one flat, simple, and horizontal, the other more complicated and vertical, forming with the first plate an angle of about forty-five degrees.

The **Horizontal, or Palatine, Plate** has two surfaces and four borders.

The **lower surface** (Figs. 250, 251) prolongs the hard palate backward and is irregularly four-sided. The **inner or median border** is straight and serrated, and joins the opposite palatine, continuing backward the straight suture which divides the roof of the mouth into two

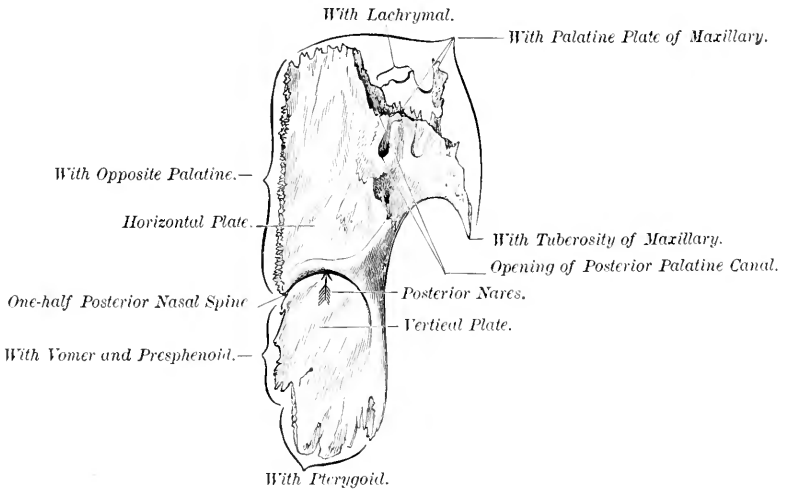
FIG. 249.



symmetrical halves. The posterior end of the median border is prominent, and contributes one-half of the **posterior nasal spine**. The **posterior border** is emarginate, and curves into the lower border of the vertical plate. The **anterior border** is roughened, and bevelled at the expense of the lower surface; it runs outward and backward, reducing the length of the outer border to almost half the length of the inner border. Its outer part lies close to the lower part of the anterior border of the maxillary process of the vertical plate, and

parallel to it. The anterior border articulates throughout its length with the posterior edge of the horizontal plate of the maxillary bone. The **outer border** begins at the back of the maxillary process of the vertical plate, and runs inward and forward, then backward and inward. It is rounded, and forms also the lower border of the vertical plate. The lower surface of the horizontal plate is smooth, and somewhat elevated at its middle in an antero-posterior line. Near the anterior border, and sometimes within it at some distance from the

FIG. 250.



LEFT PALATINE BONE, LOWER ASPECT.

median border, is a well-marked foramen, the palatal opening of the posterior palatine canal. There are, as a rule, several smaller foramina behind the principal one and external to it. The lower surface is covered by the mucous membrane of the mouth.

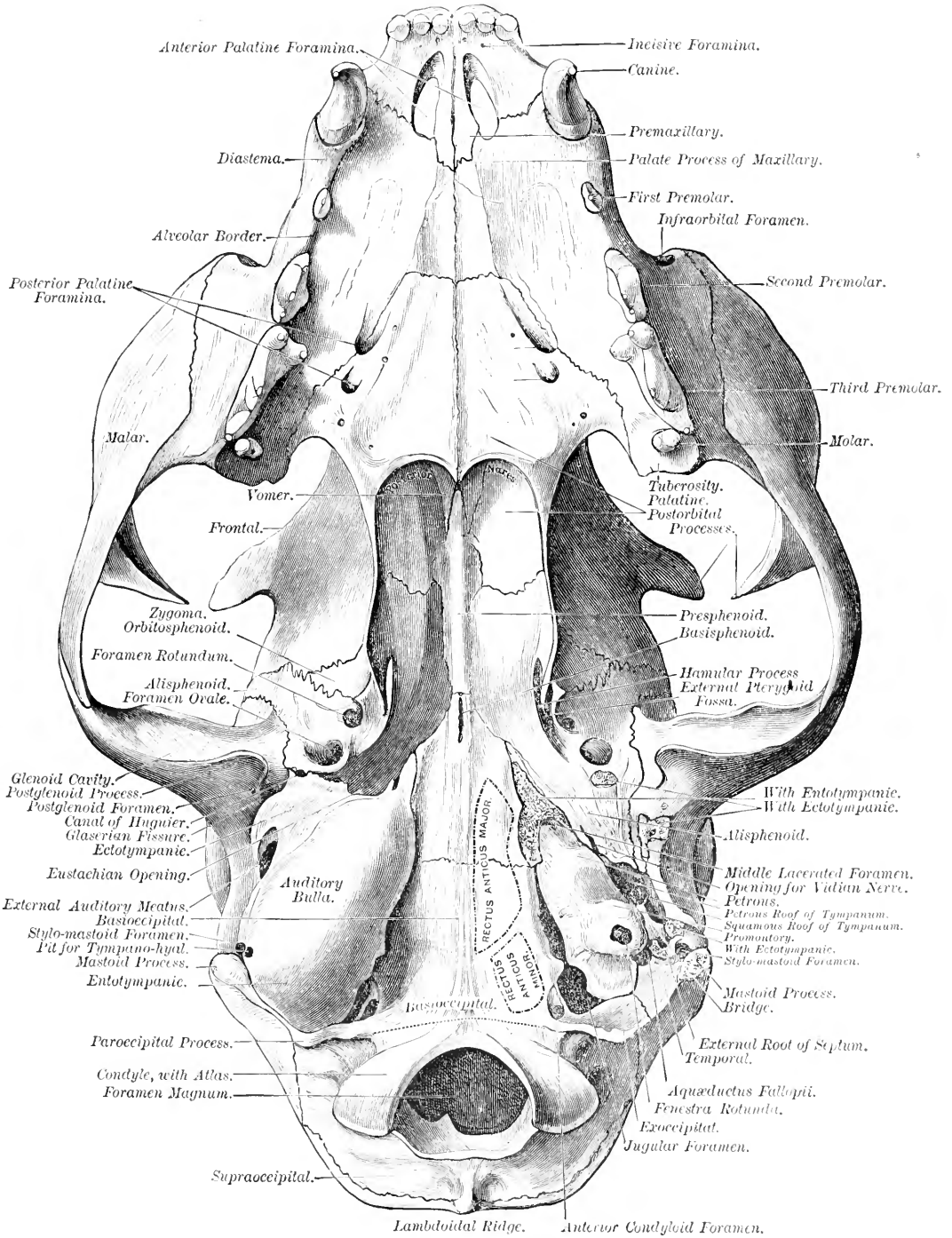
The **upper surface** of the horizontal plate (Fig. 252) has the same general shape as the lower surface. It is not so wide, however, inasmuch as the vertical plate, the base whereof is thick in front, springs from its outer border. It is slightly concave from side to side, and convex from before backward. The anterior end of the inner border is sometimes elevated, and gives rise with the bone of the opposite side to a short **crest** which articulates with the vomer. The upper surface forms the floor of the back of the nasal chamber and of the posterior narial canal (Fig. 269).

The **Vertical Plate** may be said to consist of three parts: an outer anterior hooked maxillary process; a high anterior and upper



FIG. 251.

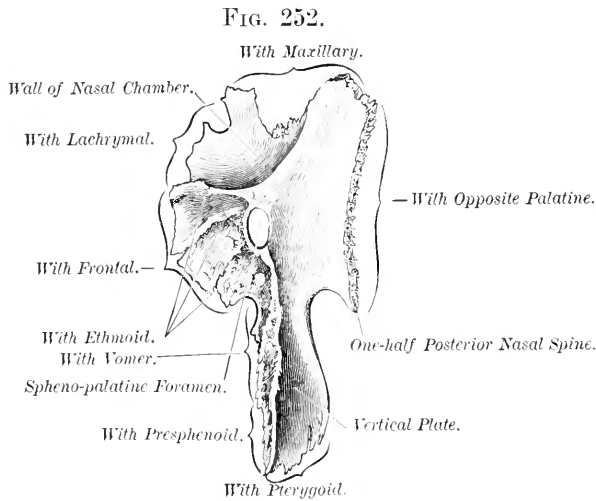
Incisors.



THE SKULL, LOWER ASPECT.

ethmoidal process; and a long narrower posterior sphenoidal process.

The maxillary process (Fig. 253) is in the form of a hook. Its outer border is thin behind, but widens in front and gives off the anterior border of the horizontal plate of the bone. It is rough, and ends in a sharp angle where it joins the anterior border of the vertical plate; it articulates with the inner side of the tuberosity and of the orbital plate of the maxillary. It faces outward and forward. The



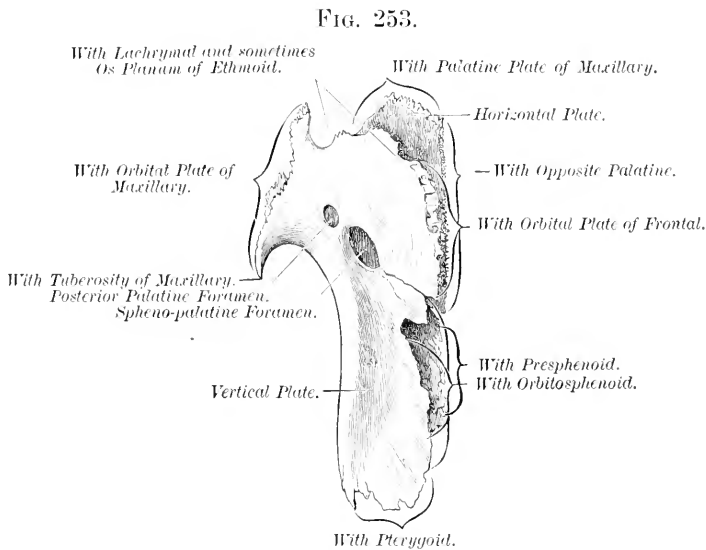
LEFT PALATINE BONE, UPPER ASPECT.

posterior border of the process is rounded and deeply emarginate; it curves into the outer border of the bone. At the base of the process, equidistant from the outer and posterior borders, is a round foramen leading into the posterior palatine canals, which run inward and forward to open at the front part of the lower surface of the palatine plate.

The ethmoidal process of the vertical plate rises from the base of the maxillary process as a thin scale of bone sloping upward and inward. Its anterior border is jagged, and joins the posterior border of the lachrymal, or of the os planum of the ethmoid; it faces forward and upward. Its superior border is nearly straight, or slightly arched, and articulates with the orbital plate of the frontal. The posterior limit is indicated by a fissure extending from the superior border downward and forward to the large foramen. The small triangle behind the fissure and in front of a sharp vertical

border belongs to the sphenoidal process. The outer border is short and rounded; it is directed backward and inward, and is continuous with the outer borders of the maxillary process in front and the sphenoidal process behind. In shape the ethmoidal process is oblong; it lies at the bottom of the orbit, between the maxillary, the lachrymal, the frontal, and the orbitosphenoid.

Its outer, or orbital, surface is smooth, and slightly concave from above downward. Below and behind the middle is the large, oval, **spheno-palatine foramen**, for the transmission of the posterior nasal vessels and nerves. A ridge, more or less distinctly marked, runs from this foramen upward and backward to the posterior margin,

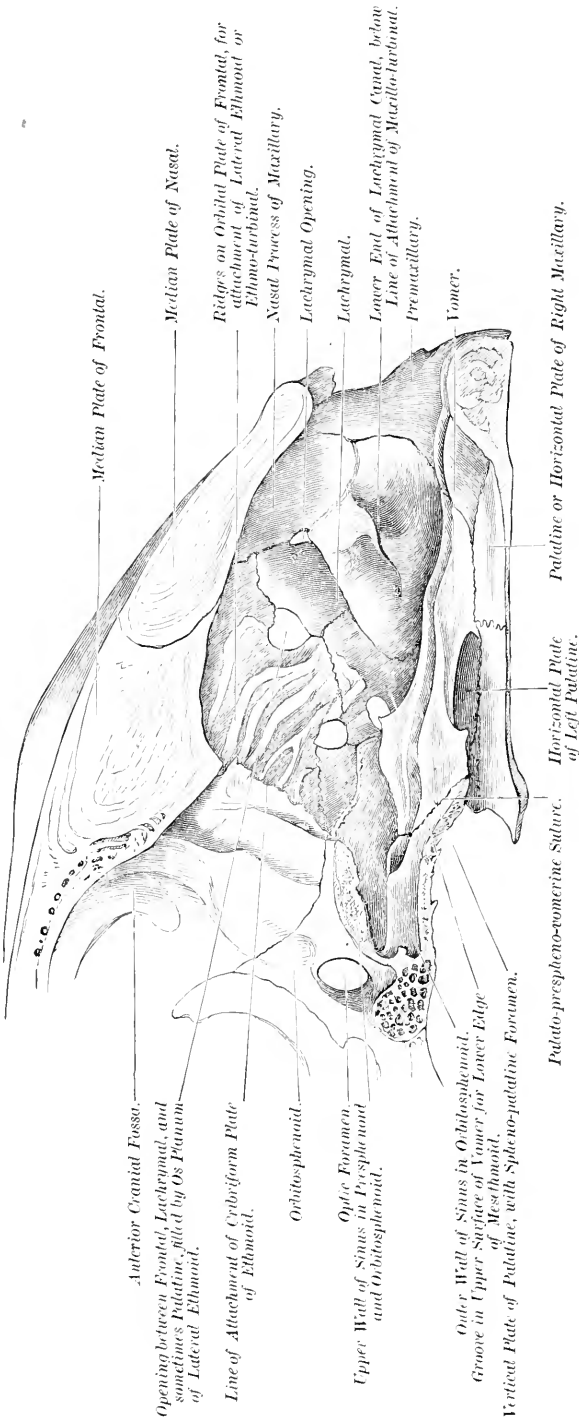


LEFT PALATINE BONE, ORBITAL ASPECT.

whence it is continued on the side of the orbitosphenoid. It marks the upper line of attachment of the external pterygoid muscle. Above this ridge, running in the same direction, but forming an angle with it, is the fissure leading from the foramen to the upper border.

The inner, or nasal, surface of the ethmoidal process of the vertical plate (Figs. 252, 254) is rough and marked by ridges running downward and forward. These ridges are continuous with the ridges on the inner surface of the frontal and orbitosphenoid bones, to which are attached the partitions of the lateral ethmoid. In some specimens these ridges are not distinctly marked; in well-developed skulls, however, they are three in number, arranged as follows:

FIG. 254.

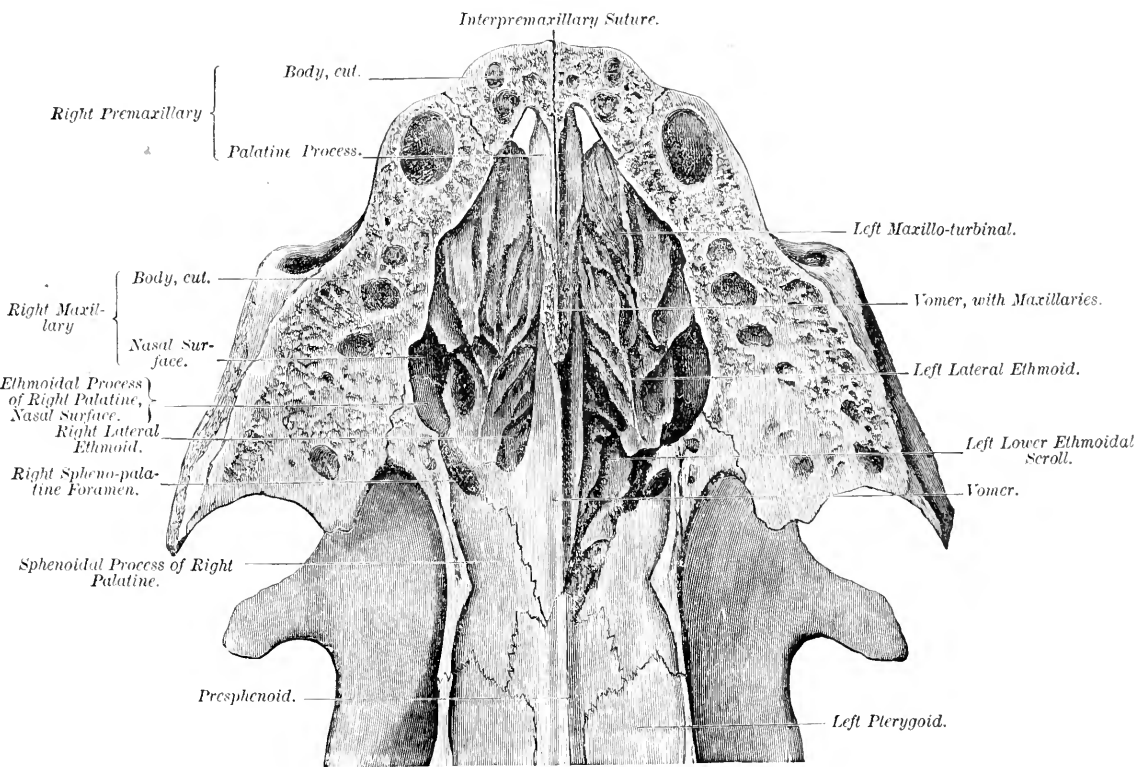


OUTER WALL OF LEFT NASAL CAVITY FROM WITHIN, ETHMOID REMOVED.

The posterior and shortest ridge is directed backward and upward from the posterior part of the rim of the spheno-palatine foramen ; it joins the last partition on the external surface of the lateral ethmoid, and divides the ethmoidal process from a triangular area on the inner surface of a small almost vertical part of the sphenoidal process which overlaps the side of the orbitosphenoid.

The second ridge begins at the anterior end of the spheno-palatine foramen and passes to the superior border parallel with the first; it joins the penultimate partition of the lateral ethmoid.

FIG. 255.



NASAL FOSSÆ FROM BELOW.

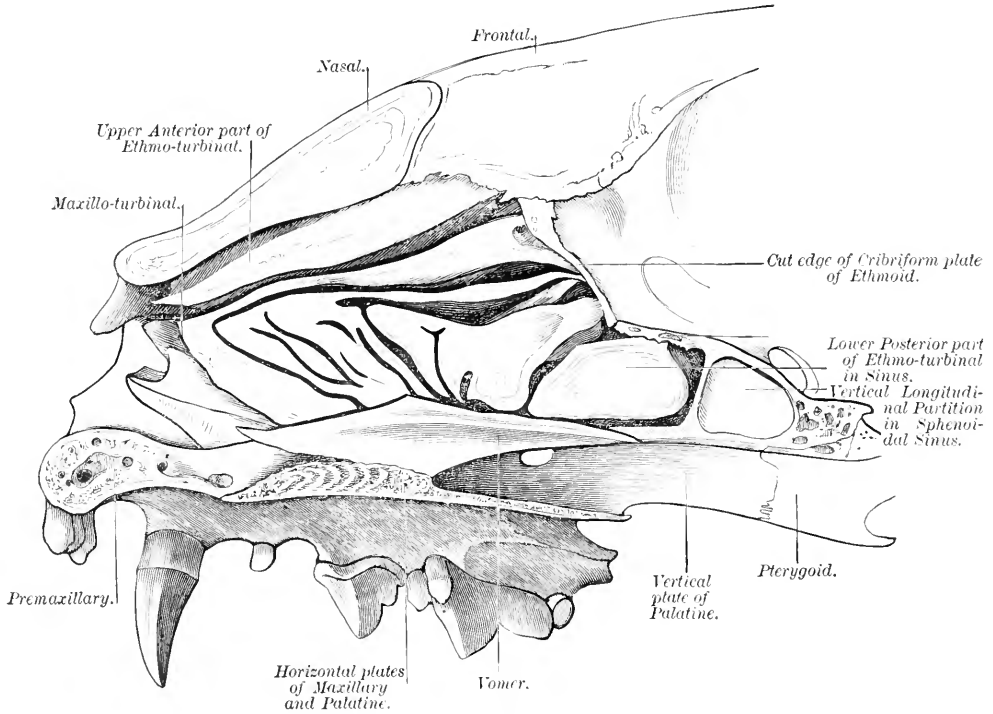
Palatine Processes of Maxillaries and Palatines removed. Left side of posterior part of Vomer cut away.

The third or anterior ridge begins with the second, but runs almost vertically; it joins the posterior edge of the plate which forms the posterior margin of the ethmoidal cleft. The triangular area in front of this ridge is often deeply concave and forms with the side of the ethmoidal plate the posterior part of a well-marked nasal fossa, which corresponds to the human maxillary sinus. The curved ridge which

bounds the sphenopalatine foramen above joins the lateral edge of the vomer and the lower edge of the lateral ethmoid.

The sphenoidal process of the vertical plate (Figs. 253, 255, 256, 257) is in the form of a thin oblong strip of bone which runs backward from the posterior lower border of the ethmoidal process. It slopes

FIG. 256.



RIGHT NASAL CHAMBER, SIDE VIEW FROM WITHIN.

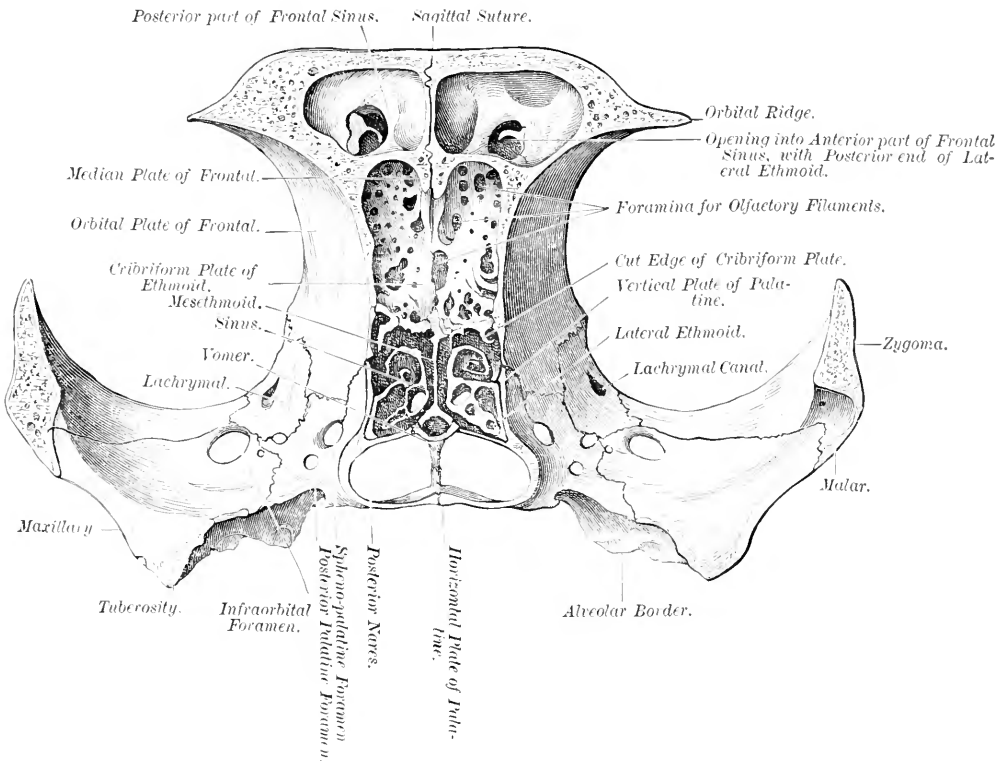
inward and upward, and, with the exception of a small anterior part behind the sphenopalatine foramen, forms with the horizontal plate a smaller angle than does the ethmoidal part. It is twice as long as high. The lower border is rounded and bounds laterally the posterior nares. The upper border is wide, rough, and bevelled. Its inner part is continued forward as far as the sphenopalatine foramen; it overlaps the edge of the vomer and articulates also with the presphenoid. Its outer part joins the upper border of the ethmoidal process and overlaps the orbitosphenoid. The posterior border is serrated and joins the pterygoid.

The outer surface is slightly concave in both directions, and faces outward and upward. It gives origin through most of its extent to the external pterygoid muscle.

Its inner surface is concave from above downward, and nearly straight from before backward. It faces downward and inward, forming the roof and the outer wall of the posterior narial passage.

**Nomenclature.**—*Palatum* is the roof of the mouth; hence this bone is known as the palate or palatine bone, or as *os palatinum*. The French name is *le palatin*; the German, *das Gaumenbein*.

FIG. 257.



TRANSVERSE VERTICAL SECTION OF SKULL THROUGH ORBITS, SEEN FROM BEHIND.

**Determination.**—When the palatine is held with the vertical plate uppermost and the anterior larger end away from the student, the maxillary process points to the side to which the bone belongs.

**Articulation.**—The palatine articulates with the maxillary, the lachrymal, the frontal, the ethmoid, the presphenoid, the orbitosphenoid, the vomer, the pterygoid, and the opposite palatine.

**Muscular Attachments.**—The palatine furnishes attachment by its orbital surface to the external pterygoid, and by its postnasal spine to the *azygos uvulæ*.

**Ossification.**—The palatine appears to develop from a single centre of ossification.

VARIATIONS IN THE PALATINE BONES.

VARIATIONS IN SIZE.

The following measurements of the palatines have been taken on bones from the left side of the skull :

The maximum length is the distance from the most prominent point of the anterior edge of the horizontal plate to the most prominent point of the posterior edge of the sphenoidal process projected on a line parallel with the median border of the bone.

The maximum width is taken, transversely to the preceding measurement, from the median border of the horizontal plate to the outer edge of the hook on the maxillary process.

The length of the horizontal plate is the distance along the median border from the tip of the postnasal spine to a point projected as far forward as the most prominent point of the anterior border.

The height of the vertical plate is the distance from the outer edge of the tip of the maxillary hook to the upper edge of the ethmoidal process at a point just behind the spheno-palatine foramen.

Maximum Length.	Maximum Width.	Horizontal Plate. Length.	Vertical Plate. Height.	Maximum Length.	Maximum Width.	Horizontal Plate. Length.	Vertical Plate. Height.
32	14	20	15	27	11	15	14
31	15	17	14	26	13	17	14
31	14	18	14	26	13	16	14
30	14	17	15	26	13	15	13
30	13	17	15	26	12	16	12
30	12	18	15	25.5	12	16	13
29	14	17	13	25	13	17	14
28	15	16	14	25	12	16	14
28	14	18	13	25	12	16	13
28	13	17	13	25	11	16	12
27.5	12	16	13	25	11	14	11
27	13	17	14	20	10	14	9
27	13	17	13				

VARIATIONS IN FORM AND DEVELOPMENT.

The horizontal plate may be narrow and prolonged forward far beyond the vertical process ; it may be wider, shorter, and more nearly quadrate. Its inferior surface near the posterior external angle is not infrequently marked by a strong tubercle. The lower openings of the posterior palatine canals exhibit variations. In some specimens there is a single large foramen in the anterior border, or just behind it ; in



others, one large foramen and a second smaller one much further back on the palatal surface; in others, one large foramen and two smaller posterior foramina; and more rarely, the large foramen may be accompanied by three or even more smaller openings. It is not clear that all these are the openings of accessory palatine canals; usually not more than two can be traced back to the posterior wall of the main canal.

On the nasal surface of the bone, sometimes on the inferior or palatal surface, near the posterior border, where the horizontal and vertical plates meet, one foramen or several small foramina are often visible.

In all the specimens examined the **posterior palatine foramen** was always present, although in some cases it was reduced in size. In a few of the bones a very small accessory foramen was seen on the orbital surface just behind the large opening and appeared again on the palatal surface close to the external border.

The **spheno-palatine foramen** is constant, and never confluent with the posterior palatine foramen. It varies in shape from oval to round, and may be reduced to the size of the posterior palatine opening. In one specimen its upper edge was wanting.

The fissure leading upward from the spheno-palatine foramen and separating the ethmoidal and the sphenoidal process is very rarely absent. In one specimen a foramen was observed in the ethmoidal process above the spheno-palatine foramen.

#### HUMAN PALATINE BONES.

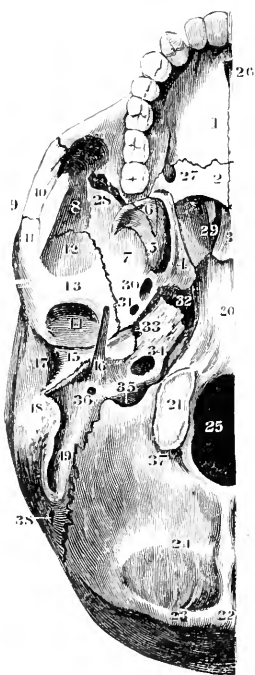
The base of the human skull is so greatly compressed along antero-posterior lines that the pterygoid processes almost touch the maxillary tuberosities, only small wedge-shaped pyramidal processes of the palatines intervening (Fig. 258). The horizontal plates of the palatines are reduced to narrow strips which do not project backward to form the lateral inferior margins of the posterior nares.

On the side of the skull (Fig. 260) this compression is most clearly shown in the region of the zygomatic fossa,—namely, the space between the temporal, the malar, the maxillary, and the sphenoid, where the lateral part of the sphenoid and the posterior part of the maxillary are almost in contact. They are separated, however, by a vertical slit, in the bottom of which, forming an inner wall, is part of the outer surface of the high and narrow palatine.

The ventral part of this slit is known as the **pterygo-maxillary**

fissure (Fig. 259); it is bounded by the pterygoid process, the maxillary, and the palatine; it terminates below in the posterior palatine

FIG. 258.



EXTERNAL VIEW OF THE BASE OF THE SKULL. RIGHT SIDE.

1, palatine plate of the maxillary; 2, palatine plate of the palatine bone; 3, vomer; 4, 5, internal and external pterygoid plates; 6, pyramidal process of the palatine bone; 5, 6, occupy the pterygoid fossa; 7, under part of the great wing of the sphenoid bone, forming part of the zygomatic fossa; 8, temporal surface of the great wing of the sphenoid bone; 9, zygoma; 10, zygomatic process of the malar bone; 11, zygomatic process of the temporal bone; 12, squamous portion of the temporal bone; 13, articular eminence; 14, glenoid fossa; 15, tympanic plate; 16, styloid process; 17, auditory meatus; 18, mastoid process; 19, digastric fossa; 20, conjunction of the basilar process and body of the sphenoid bone; 21, occipital condyle; 22, occipital protuberance, and crest leading from it downward; 23, 24, superior and inferior semicircular lines; 25, occipital foramen; 26, anterior palatine fossa; 27, posterior palatine foramen; 28, sphenomaxillary fissure; 29, posterior naris; 30, foramen ovale; 31, foramen spinosum; 32, lacerate foramen; 33, Eustachian tube; 34, entrance of the carotid canal; 35, jugular foramen; 36, stylo-mastoid foramen; 37, pit with a posterior condyloid foramen; 38, mastoid foramen.

canal, and enlarges above into the dorsal part, or **spheno-maxillary fossa**, which is bounded by the front of the roots of the pterygoid process and great wing of the sphenoid, and by the palatine and the maxillary.

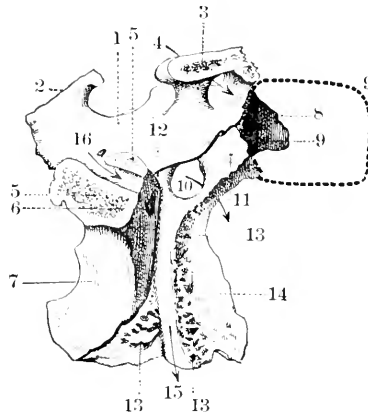
The upper part of the spheno-maxillary fossa is prolonged outward and forward between the maxillary and the large wing of the sphenoid, as the **spheno-maxillary fissure**, which, inasmuch as it separates the outer and lower walls of the orbit, is also known as the **inferior orbital fissure**.

The spheno-maxillary fossa communicates on the outer side with the zygomatic fossa; below with the cavity of the mouth through the posterior palatine canals; above with the orbit; on the median side with the cavity of the nose through the spheno-palatine foramen piercing the vertical plate of the palatine. Into the back of the fossa open the foramen rotundum, the Vidian canal, and the pharyngeal canal, sometimes called the pterygoid canal.

When we compare the human palatine (Figs. 261, 262) with the palatine of the cat, we recognize at a glance the great change which has taken place by reason of the reduction of the antero-posterior length and the increase in the dorso-ventral height. The horizontal plate projects forward only slightly be-

yond the vertical plate; the posterior part, which in the cat is very long, is almost entirely wanting; the posterior palatine and spheno-

FIG. 259.

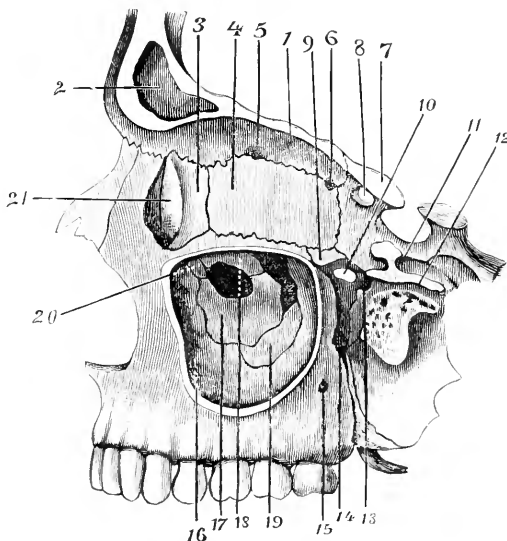


RELATIONS OF THE SPHENOID AND PALATINE BONES.

1, body of the sphenoid; 2, dorsum sellae; 3, divided lesser wing; 4, optic foramen; 5, divided root of great wing; 6, Vidian canal; 7, external pterygoid plate; 8, sphenoidal rostrum; 9, position of the orbital plate of the ethmoid; 10, sphenopalatine foramen in sphenomaxillary fossa; 11, ethmoidal process of palatine; 12, sphenoidal process; 13, rough surfaces for the maxillary; 14, maxillary process; 15, posterior palatine canals leading down from the pterygo-maxillary fissure; 16, foramen rotundum.

palatine foramina are thus brought near the posterior edge of the bone. The superior-anterior part of the maxillary process, the ethmoidal process, and the sphenoidal process do not spring directly from the outer edge of the horizontal plate, as do these parts of the vertical

FIG. 260.



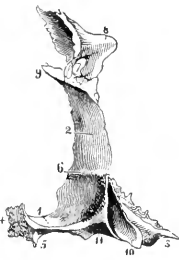
LEFT SIDE OF FACE, OUTER WALLS OF THE ORBIT AND ANTRUM REMOVED.

1, frontal orbital plate; 2, frontal sinus; 3, lacrimal bone; 4, ethmoid bone; 5, 6, ethmoidal foramina; 7, sphenoid bone; 8, optic foramen; 9, palatine bone, ethmoidal process; 10, sphenopalatine foramen in inner wall of sphenomaxillary fossa; 11, foramen rotundum; 12, Vidian canal; 13, pharyngeal canal; 14, termination of the pterygo-maxillary fissure in the posterior palatine canal; 15, posterior dental canal; 16, inner wall of the antrum formed by the maxilla; 17, maxillo-turbinal bone; 18, uncinate process of the ethmoid; 19, palatine bone; 20, descending process of the lacrimal behind which is the opening of the antrum into the nasal cavity; 21, lacrimal fossa.

plate in the cat, but are elevated on a high nasal plate the inner surface of which is crossed by a backward extension of the crest for the maxillo-turbinal. In the cat this crest fades away behind on the posterior part of the nasal surface of the maxillary bone.

The posterior border of this nasal plate (Fig. 261), the lower part of the posterior border of the entire bone, is prolonged downward and

FIG. 261.



RIGHT PALATINE BONE. POSTERIOR VIEW.

1, palatine plate; 2, nasal plate; 3, pyramidal process; 4, articular border for the left palatine bone; 5, posterior nasal spine; 6, turbinal crest; 7, sphenopalatine notch, between 8, the ethmoidal, and 9, the sphenoidal process; 10, groove for the internal pterygoid plate of the sphenoid bone; 11, position of the posterior palatine canal.

FIG. 262.



RIGHT PALATINE BONE. EXTERIOR VIEW.

1, rough surface articulating with the maxillary and diminishing the aperture of the antrum; 2, posterior palatine canal, completed by the maxillary; 3, sphenopalatine notch; 4, 5, 6, ethmoidal process; 4, surface directed towards the sphenomaxillary fossa; 5, orbital surface; 6, maxillary border; 7, sphenoidal process; 8, pyramidal process.

outward into the pyramidal process, or tuberosity. It presents a rough external area for the external pterygoid plate of the sphenoid; a smooth middle groove, which, coming between the two pterygoid plates, forms part of the anterior wall of the external pterygoid fossa (Fig. 258), and an internal groove, which receives the internal pterygoid plate.

In a notch between this groove and the edge of the horizontal plate are the openings of the accessory posterior palatine canals. The posterior border of the nasal plate is continued upward to the posterior border of the small sphenoidal process, and articulates with the internal pterygoid plate.

On the external surface of the nasal plate (Fig. 262) the outer side of the pyramidal process and the lower border are rough and join the tuberosity of the maxillary; they correspond to the surface and border on the hook-like extension of the maxillary process in the cat. In front of the rough triangular area on the tuberosity is a deep groove or canal, the posterior palatine canal, which is continued upward to the external surface of the sphenoidal process as the smooth inner wall of the pterygo-maxillary fissure. In front of the groove

the external surface is rough and overlaps the nasal surface of the maxillary; an extension forward, sometimes called the **maxillary process**, covers part of the nasal orifice of the maxillary antrum (Fig. 260).

The small **sphenoidal process** rises from the top of the posterior angle and curves upward and inward. Its **superior surface** is applied to the lower surface of the sphenoturbinal of the sphenoid, and is marked by a longitudinal groove which the sphenoid converts into the pharyngeal canal. Its **external surface** is bevelled behind for the internal pterygoid plate, and is smooth in front where it forms part of the wall of the sphenomaxillary fossa. The **internal surface** is concave, and is part of the wall of the nasal cavity. The **anterior border** is the posterior border of the sphenopalatine notch, sometimes a true foramen, but usually converted into one by the sphenoturbinal.

Above and in front of the notch is the **ethmoidal, or orbital, process**, which is quadrate and more or less hollow. Although small, it presents five surfaces, whereof two are non-articular,—namely, the **superior, or orbital**, which forms a small area on the posterior medial wall of the orbit, and the **external, or zygomatic**, which enters into the superior-anterior wall of the sphenomaxillary fossa and hence faces outward and backward toward the zygomatic fossa. Of the articular surfaces, the **anterior-inferior** joins the maxillary, the **posterior-superior** joins the outer edge of the sphenoturbinal, and the **internal, or ethmoidal**, faces upward, forward, and inward to join the lateral ethmoid. The cavity in the interior of the ethmoidal process opens widely, sometimes on the posterior-superior surface, sometimes on the internal surface.

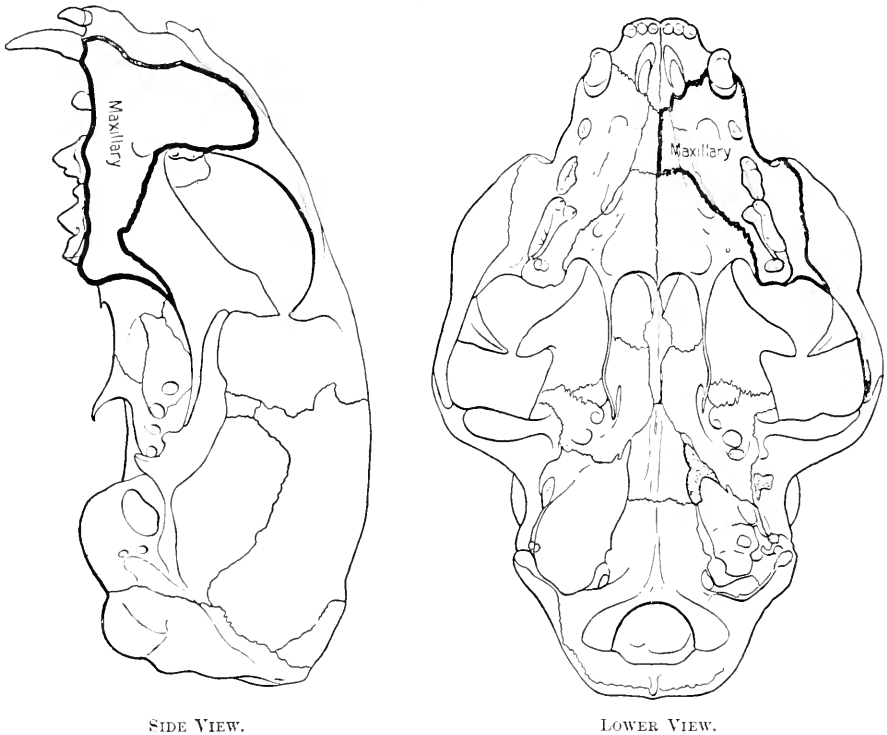
The small **palatine plate** presents few noteworthy features. The median margins of both the superior and inferior surfaces are raised into strong **crests**. The **inferior surface** exhibits close to its outer margin the openings of the posterior palatine and accessory posterior palatine canals; the latter can be traced upward to the inner and posterior wall of the main canal.

#### THE MAXILLARY BONES.

**General Description.**—The Maxillaries are paired bones which form the greater part of the upper jaw and of the face. They contribute also largely to the outer walls and the floor of the nasal cham-

bers, the floors of the orbits, and the roof of the mouth (Fig. 263). In them are implanted the larger and most important of the upper teeth. They are in contact with each other for a short distance below, while assisting in the formation of the hard palate, but they are

FIG. 263.



POSITION OF THE MAXILLARY BONE.

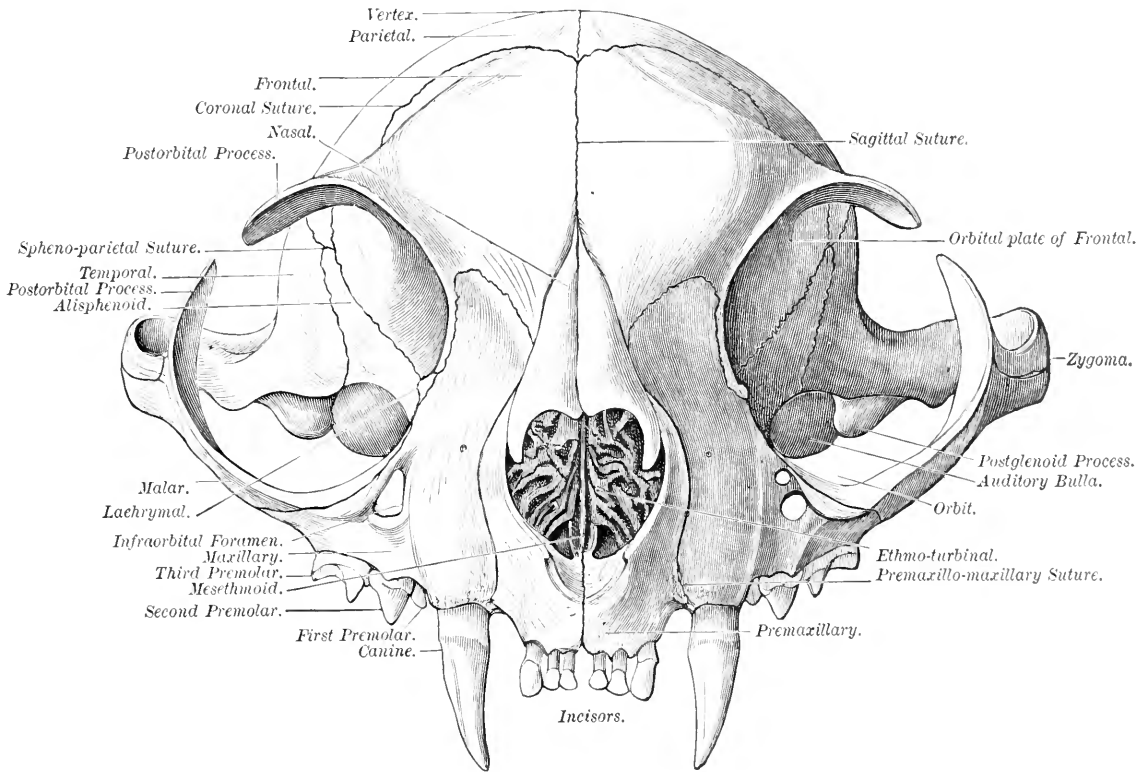
separated from each other in front by the premaxillaries, behind by the palatines, and above by the nasals, the lachrymals, and the frontals.

Each maxillary may be described as consisting of a bony bar, or body, and three processes. The body is narrow in front and wider behind. The upper teeth are embedded in its lower surface. The three processes arising from the body are: from its inner surface, a broad horizontal palatine plate; from its upper surface, in front, a high nasal process which slopes inward; and from the back part, a low malar process which slopes outward.

The **Body** has five surfaces: an external or facial, a superior or orbital, an inferior or oral, an internal or nasal, and a posterior or zygomatic.

The **external surface** (Figs. 264, 265) is about four times as long as high, and somewhat higher in front than behind. It faces outward and forward, and in its anterior third, which passes above into the external surface of the nasal process, it faces upward also. In its posterior two-thirds it faces slightly downward as a continuation of the malar process. Its **anterior margin** is nearly vertical, and sinuate.

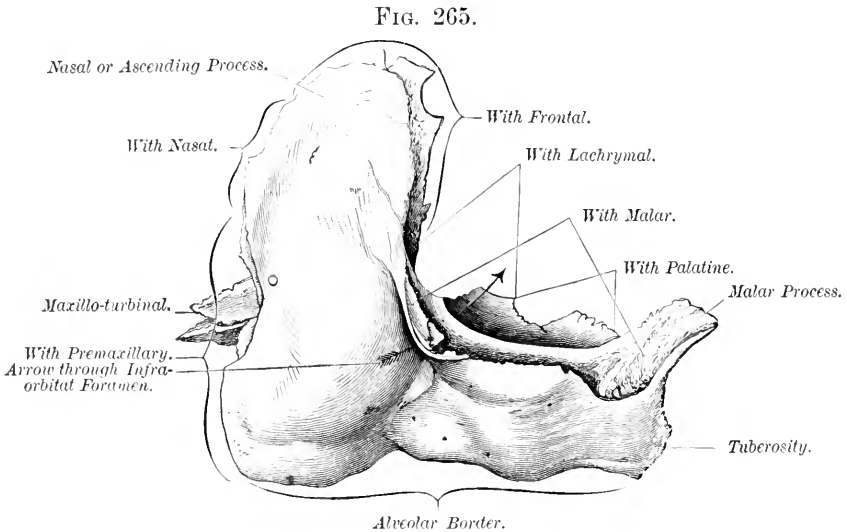
FIG. 264.



SKULL, FRONT VIEW.

A rough triangular space included between two sharp, curved crests articulates with the premaxillary bone. A little behind this space is an oblique swelling which indicates the position of the root of the canine tooth and is called the **canine eminence**. Behind the eminence is a vertical fossa, more or less well marked, known as the **canine depression**. Just above this depression is the large oval **infraorbital foramen**, passing through the anterior part of the malar process and transmitting vessels and nerves. This foramen varies greatly in size; sometimes there are two foramina, the additional foramen being small and placed above the other and on its inner side. The rest of the

surface is marked by lesser depressions at the intervals between the premolar teeth. On a posterior flat triangular area, which extends upward on the malar process, is attached the masseter muscle. The lower margin of the surface is straight, and shows the emargination



LEFT MAXILLARY BONE, OUTER SURFACE, SIDE VIEW.

due to the alveoli<sup>1</sup> or teeth sockets. The posterior border is short, vertical, and rounded, passing backward above into the posterior border of the malar process.

The superior or orbital surface (Fig. 266) is half as wide as long, and wider behind than in front, where it ends as the floor of the infra-orbital foramen. It is faintly concave from side to side, and faces upward, inward, and slightly backward. It is marked by many small inconstant foramina, the openings into dental canals. One large foramen near the front of the inner margin appears to be constant. The posterior margin of the superior surface is emarginate and rounded, passing down into the posterior, or zygomatic, surface. It is directed forward and outward. Near its inner end is a small oblique notch.

The inner border is divided into three nearly equal parts :

The first part begins as a sharp, elevated line at the inner margin of the infraorbital foramen, separates the orbital surface from the nasal surface of the palatine plate, and runs backward and inward to end

<sup>1</sup> *Alveolus*, a small cavity.

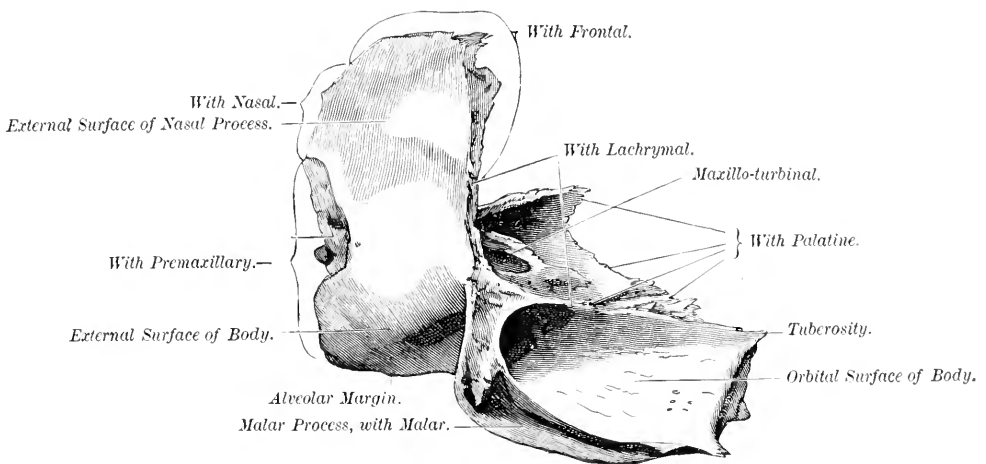


where the second part begins. It articulates with the lower edge of the lachrymal bone.

The **second part** begins at the end of the first part as a jagged, raised suture, separating the same surfaces as the first part, and runs backward. It articulates with the outer border of the maxillary process of the palatine.

The length of the **third part** of this border varies in proportion as the second part is longer or shorter. It is rounded, directed outward and backward, and ends in a sharp angle with the posterior border.

FIG. 266.



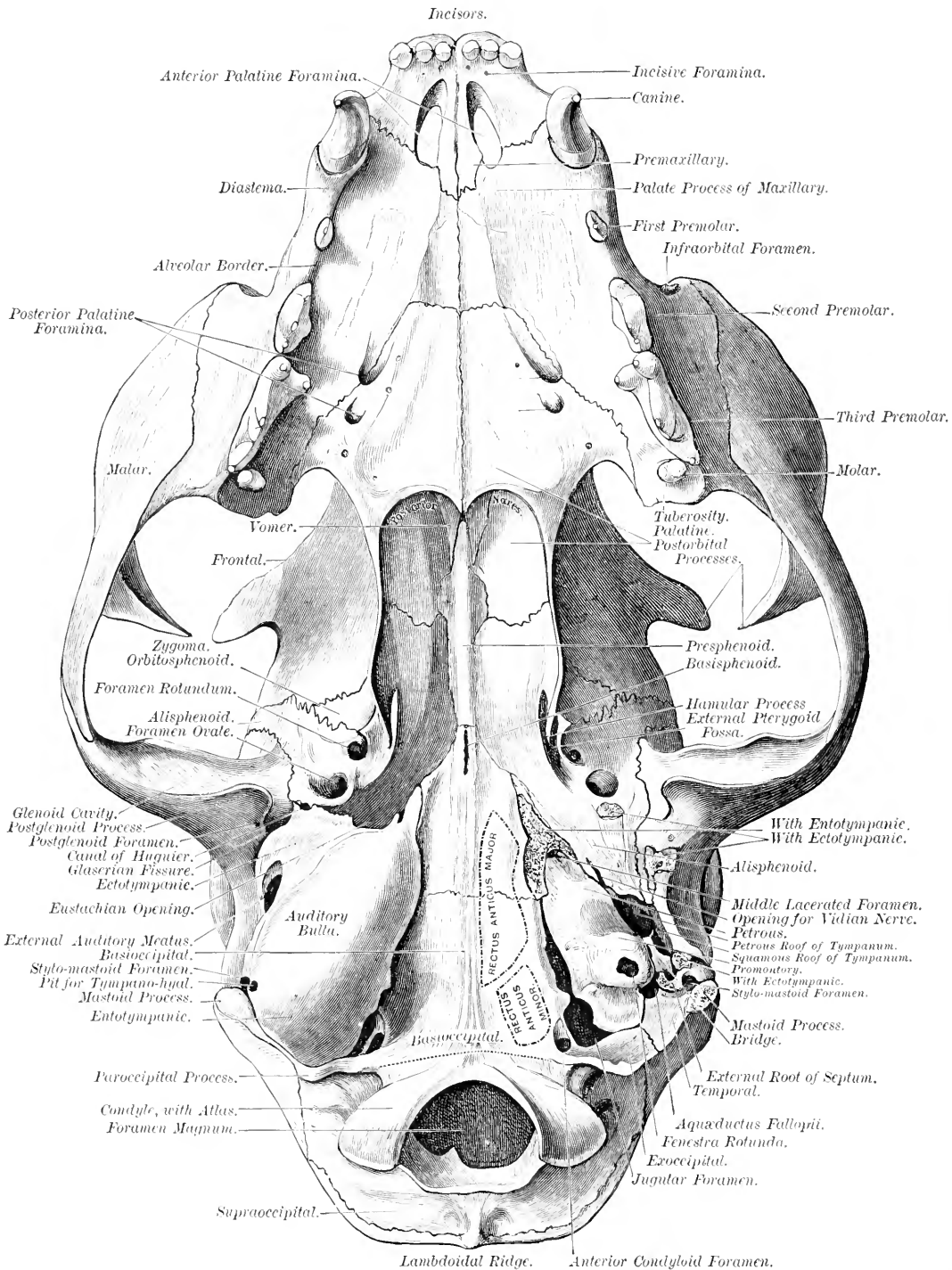
LEFT MAXILLARY BONE, SUPERIOR AND OUTER ASPECTS.

It is a free border, forming the outer edge of the notch seen between the palatine and the maxillary at the inner posterior edge of the bony floor of the orbit.

The orbital surface is limited **externally** by the sharp inner edge of the malar process. The **anterior boundary** of this surface is the lower margin of the infraorbital foramen.

The **inferior surface** (Fig. 267), for a little more than half its length, is merely the alveolar ridge, inasmuch as the plane surface lying on its inner side, and into which it passes without a dividing line, is regarded as the inferior surface of the palatine plate. At the front part of the large premolar tooth, indicated in the bone in which the teeth are lost by the two small transversely placed sockets, the body widens out and has an **internal edge** of its own, which is directed outward and backward and is serrated for articulation with the pala-

Fig. 267.



THE SKULL, LOWER ASPECT.

tine bone. This part corresponds quite closely to the orbital surface which lies above it. The **posterior edge** is directed outward and backward from the prominent inner angle. The **external edge** of the outer surface bounds the series of tooth-sockets on the outer side and the facial surface below. It begins in front by curving on the outside of the cavity for the canine, then, made slightly sinuate by the tooth-sockets, it is directed backward and outward, and ends in the external angle of the **maxillary tuberosity**. The border, as a whole, is faintly emarginate.

At the extreme anterior end of the surface is the large alveolus for the canine; whereof the opening is regularly oval, the long axis being directed from in front backward. A short interval, or **diastema**,<sup>1</sup> follows this opening, and then comes the small, oblong, obliquely placed alveolus for the first premolar. This alveolus is very rarely double. The second premolar is placed behind the first, and has two, rarely three, alveoli; of these the anterior is the smaller and lies somewhat to the outside of the posterior. When there are three sockets, the additional one lies on the inner side of the other two and between them. The three succeeding alveoli belong to the third premolar. The two smaller and anterior are placed side by side transversely to the axis of the border, but the inner one is more posterior than the outer. In outline these two are irregularly oval; the long axis of the outer one is directed backward and inward, and the long axis of the inner is directed backward and outward. The outline of the third socket is twice as long as wide, with its long axis in the long axis of the bone. Placed with its long axis nearly at right angles to the inner side of the posterior end of this third socket is the oval socket for the small molar. This is often divided into two.

The inferior surface is raised in sharp margins around the alveoli, and then slopes upward and inward into the palatine plate. At the posterior part, in front of the molar alveolus and on the inside of the large alveolus for the posterior root of the last premolar, is a deep depression.

The **inner** or **nasal surface** of the body of the maxillary is of small extent, and not easily separated from the inner surface of the nasal process above nor from the upturned outer part of the upper surface of the palatine process below. Its **upper boundary** is divided

<sup>1</sup> (Gr.) an interval.

into three nearly equal parts: first, and in front, the anterior horizontal part of the line of attachment of the maxillo-turbinal; second, the straight upper horizontal border of the swelling in that attachment which marks the course of the underlying lachrymal canal; third, the sharp border which runs downward, inward, and backward from the upper lachrymal opening to the rough space for articulation with the maxillary process and with the anterior border of the palatine bone. The **lower boundary** is the line which marks where the surface passes into the palatine process. It arches from the front outwardly, and ends behind in the upper boundary. The **anterior boundary** is nearly vertical and irregular and articulates with the premaxillary bone in front. The inner surface is divided into two portions by the lower posterior oblique part of the attachment of the maxillo-turbinal. In front and below this line is a depression for the scroll of the maxillo-turbinal, and behind and above it, a depression for the lower part of the lateral ethmoid. The lower opening of the lachrymal canal is seen at the upper part of this oblique crest.

The **posterior or zygomatic surface** (Fig. 272) is little more than a broad rounded border, which forms the maxillary tuberosity. Its upper margin is the posterior margin of the orbital surface; its lower margin is the posterior margin of the inferior surface; its outer margin is the posterior margin of the external surface. It is triangular; one angle is prolonged upward and inward as the common posterior border of the orbital surface and of the inferior surface. Another angle is prolonged upward and outward as the posterior margin of the malar process. The lower blunt angle is the posterior end of the alveolar border.

The **Palatine Plate or Process** of the maxillary is very simple; it springs from the inner side of the body and is directed inward to meet its fellow of the other side, thus forming a greater part of the roof of the mouth and the floor of the nasal chamber. It is flat and thin, its thickness being about uniform throughout its extent. It is slightly thicker, however, at the outside, where its upper surface curves up into the inner or nasal surface, and the lower surface curves down into the alveolar border. It presents three borders for articulation with neighboring bones.

The **anterior border** is short, nearly transverse, and serrated. It joins the posterior part of the body of the premaxillary; a little

portion at the inner end is rounded and faintly emarginate and forms the posterior boundary of the **anterior palatine foramen**.

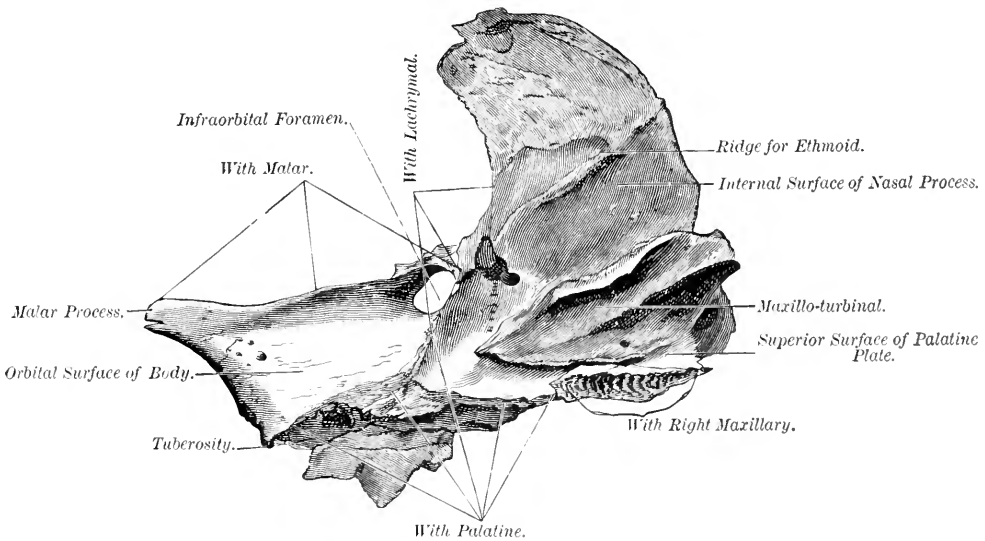
The **inner border** is serrated through its entire length. In its first third it is directed slightly inward as well as backward, and articulates with the outer part of the posterior end of the palatine process of the premaxillary. In the rest of its course it is longitudinal and joins its fellow. It forms, behind, a right angle with the posterior border.

The **posterior border** passes at first, for a short distance, directly outward. It then turns sharply and runs backward and outward to become the posterior part of the inner border of the lower surface of the body of the bone. It articulates with the horizontal plate of the palatine bone.

The **lower surface** of the palatine plate of the maxillary (Fig. 267) is nearly smooth, and slightly elevated in a longitudinal line near the inner border. Near, and in, its posterior border, at about the middle, are a notch and groove for the **posterior palatine canal**. This surface is covered by the mucous membrane of the mouth.

The **upper surface** of this process (Figs. 268, 269) has the same general form as the under surface, narrow in front and wide behind.

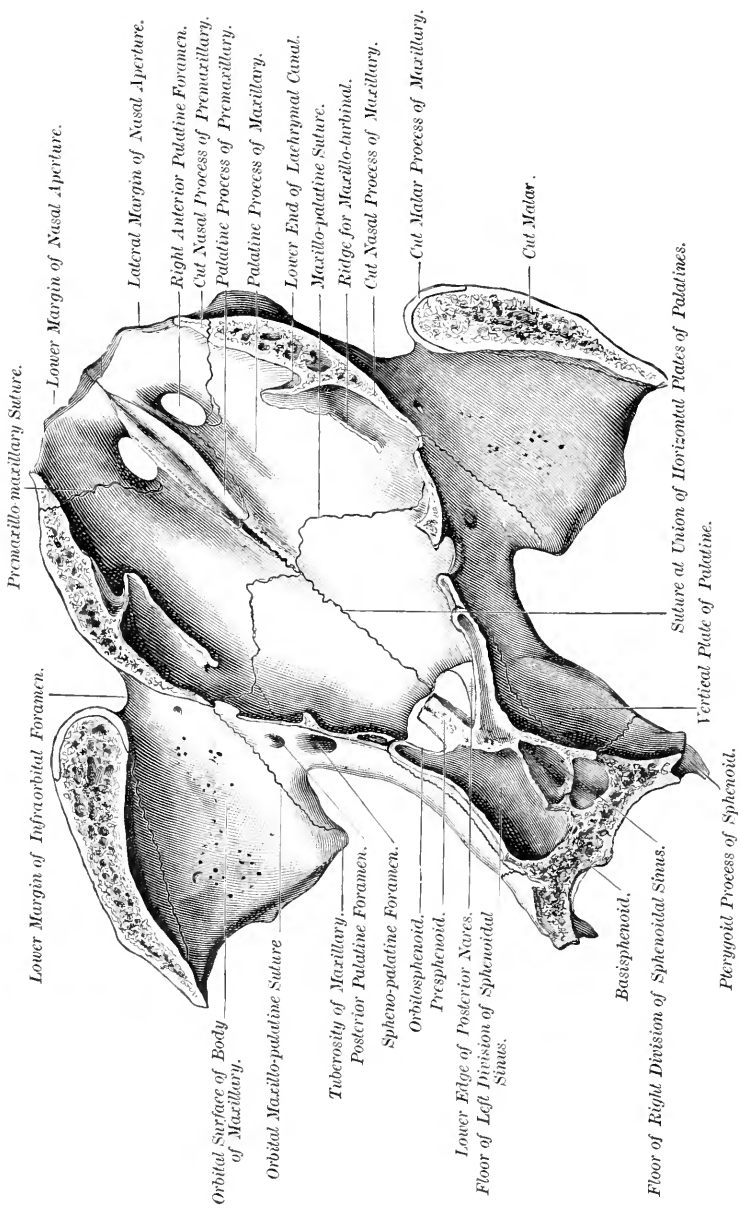
FIG. 268.



LEFT MAXILLARY BONE. SUPERIOR SURFACES.

It is elevated along the inner border to form with the opposite bone a nasal crest to which articulate in front, on the lower part, the pre-

FIG. 269.



FLOOR OF NASAL FOSSAE; ETHMOID AND MAXILLO-TURBINALS REMOVED.

maxillaries, and behind, on the higher part, the vomer. At the outer part the upper surface rises gradually into the nasal surface of the bone, but behind it is separated from it, in part, by the lower end of the crest for the maxillo-turbinal. A slight longitudinal elevation is noticeable at about the middle of the surface. On the inner side of this elevation a shallow **groove** leads forward into the anterior palatine foramen; and on the outer side, further back, a long **depression** helps to lodge the maxillo-turbinal. The upper surface is covered by the mucous membrane of the nasal chamber.

The **Nasal Process** is that part of the bone extending on the outside upward from the end of the upper limit of the infraorbital foramen and on the inside from the line of the lachrymal canal. It is about one-third higher than wide, and is directed slightly backward and decidedly inward as well as upward. It is thin and of nearly uniform thickness throughout. The nasal process has two surfaces and three borders.

The **external surface** (Fig. 265) is oblong, with its upper, anterior angle rounded. It is smooth and gently concave in both directions, and faces outward and forward. From its lower posterior part above the infraorbital foramen springs the upper anterior root of the malar process.

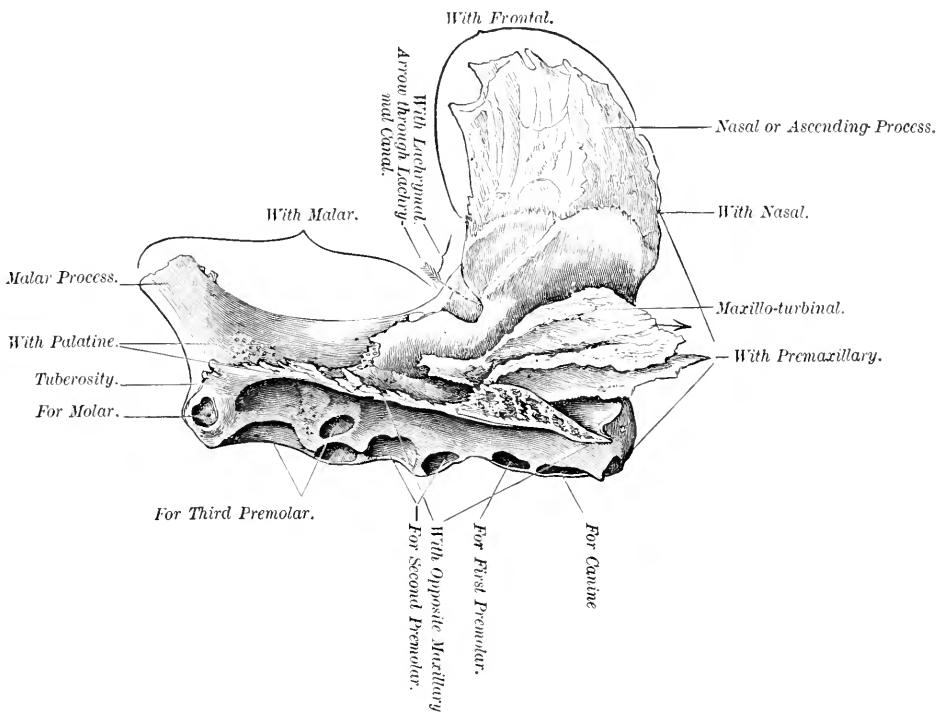
The **anterior border** is arcuate and sharp, and articulates throughout its lower half with the posterior edge of the ascending process of the premaxillary, and throughout its upper half with the outer margin of the nasal bone. Above this point may be said to begin the prominent, rounded, upper end, which fits into a deep notch in the anterior extremity of the frontal bone and is embraced by its nasal process in front and by its internal angular process behind.

The slightly emarginate **posterior border** joins, by its lower half, the lachrymal; its upper half, which is bevelled at the expense of the anterior surface, is overlapped by the external lip of the internal angular process of the frontal. At about the middle of the posterior border, above the point where the frontal and the lachrymal meet behind, there is often a swelling, known as the **lachrymal tubercle**. The upper posterior angle is prominent.

The **internal surface** (Fig. 270) of the nasal process is slightly convex from before backward. It is divided into two parts by a slightly raised curved line which marks the attachment of the cleft

plate of the lateral ethmoid. This line springs from the anterior border near its middle, arches slightly upward, and then turns boldly downward, so as to run nearly straight to the upper opening of the lachrymal canal on the posterior border. Of the two parts of the surface, the lower is bounded below by the straight line formed by the attachment of the maxillo-turbinal and the ridge for the lachrymal canal. This part is triangular, smooth, and slightly concave from above downward. It is opposite to a part of the side of the free, lower, anterior portion of the lateral ethmoid. The upper part of the inner

FIG. 270.

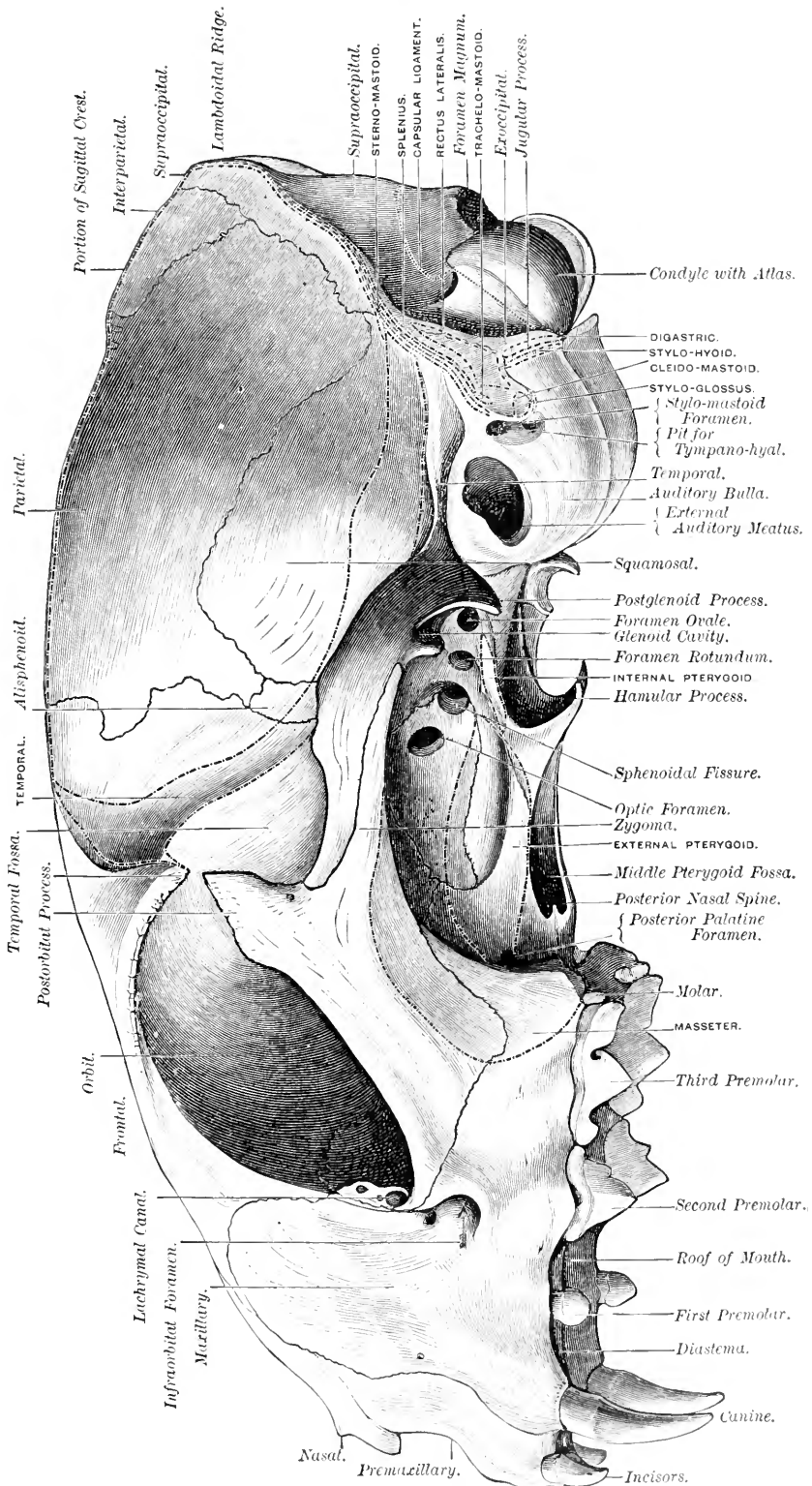


LEFT MAXILLARY BONE, INNER ASPECT, SIDE VIEW.

surface of the nasal process, above the curved line, is mostly rough, for attachment with the frontal and with the lateral ethmoid. A narrow strip along the upper part of the front margin, and a wider triangular area at the upper posterior angle and half-way down the posterior margin, mark the attachment to the frontal. The indications of the attachment of the lateral ethmoid vary in shape and in degree of development. A second curved line, above the one already described, is usually present, and is shorter, and ends on the posterior



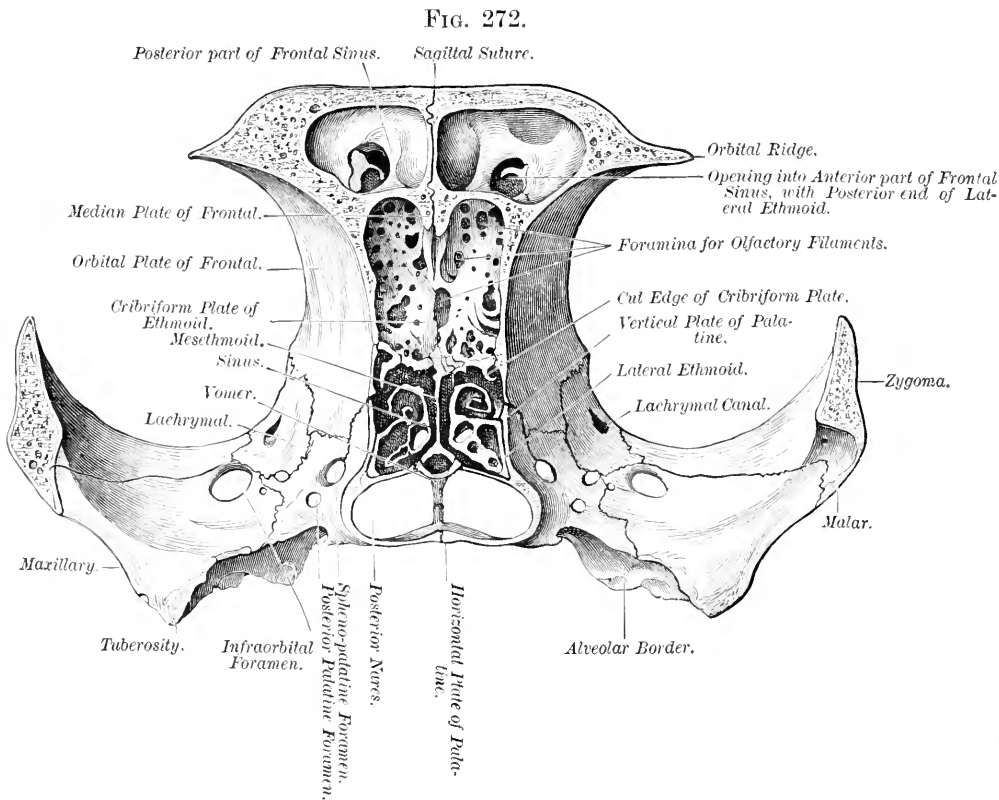
FIG. 271.



THE SKULL: THE LEFT SIDE.

border near the end of the surface for the frontal. It marks the lower front edge of the plate on the ethmoid which lies behind the ethmoidal cleft on the lateral surface, and limits its superior part in front. Below the line is a groove corresponding to the deep, lateral, triangular ethmoidal cleft on the side of the ethmoid anterior to the plate just mentioned. Above the upper curved line is an irregularly quadrate space, joined to the upper border by a narrow strip. To this part the plate of the ethmoid and its upward extension are attached.

The **Malar Process** (Figs. 265, 271) appears in the form of an upward and outward extension of the orbital surface and an upward



TRANSVERSE VERTICAL SECTION OF SKULL THROUGH ORBITS, SEEN FROM BEHIND.

and outward extension of the back part of the external surface. Between the two parts is a deep fissure which receives the anterior border of the malar. This fissure is wide in front and narrow behind. For the greater part of its extent it is at the upper edge of the process, but at the posterior part it lies on the external surface. Its outer lip is sharp, arched, and directed outward, but becomes indistinct as

it rises to the posterior part of the process. The inner lip is less curved, and is directed upward to form the front of the elevated posterior angle.

The **external surface** is continuous with the external surface of the body of the bone, and is smooth and convex in front, where it faces downward, inward, and forward. It is flattened behind, and produced upward into a curved posterior angle largely overlapped by the malar.

The **internal surface** (Fig. 272) is smooth and concave; it forms the bottom of the bony outer wall of the orbit. The malar process is connected with the base of the nasal process by a bar of bone which forms the roof of the infraorbital foramen.

The posterior margin is deeply concave, and is connected with the zygomatic surface.

**Nomenclature.**—The term maxillary comes from the Latin *maxilla*, the jaw-bone. Pliny uses *maxilla superior*, and we often find superior maxillary employed, as opposed to inferior maxillary, the lower jaw. *Os maxillare* is also employed. The Germans use *das Oberkieferbein*. The French have two words, *le maxillaire supérieur* and *le grand sus-maxillaire*.

**Determination.**—If the bone be held with its external surface toward the student, and the alveolar border below, the nasal process will be on the side to which the bone belongs.

**Articulation.**—The maxillary articulates with the premaxillary, the nasal, the frontal, the lachrymal, the malar, the palatine, the ethmoid, the maxillo-turbinal, the vomer, and the opposite maxillary.

**Muscular Attachments.**—To the maxillary are attached the **external pterygoid**, to the posterior border of the orbital surface; the **inferior oblique** of the eyeball, to the orbital surface near the posterior part of the lachrymal bone; the **masseter**, to the outer surface of the malar process; the **zygomatic**, to the external surface of the body under the malar process; the **levator anguli oris**, below the infraorbital foramen; the **levator labii superioris**, to a ridge on the outer surface of the nasal process near the lachrymal tubercle, in common with the tendon of the **orbicularis palpebrarum**; and the **levator labii superioris alæque nasi**, to the upper end of the nasal process, in common with fibres of insertion of the **occipito-frontalis**.

**Ossification.**—The maxillary develops from a single centre of ossification.

## VARIATIONS IN THE MAXILLARY BONES.

## VARIATIONS IN SIZE.

The following measurements were taken on left maxillaries.

The length of the alveolar border is the distance from the anterior edge of the canine alveolus to the posterior border behind the molar alveolus.

The height of the bone is measured on the external surface from the middle of the outer edge of the canine alveolus to the most elevated part of the superior border of the nasal process.

The width of the nasal or ascending process is its maximum antero-posterior diameter; it is found usually just below the lachrymal tubercle.

The palatal width is the greatest transverse distance from the posterior end of the median border of the horizontal plate to the outer edge of the alveolar border, usually just behind the second premolar tooth.

The height of the malar process is the vertical distance from the upper end of its posterior border to the alveolar border produced backward.

The lateral length of the orbital surface of the body is the distance from the middle of the upper rim of the infraorbital foramen to the extreme posterior tip of the malar process.

The medial length of the orbital surface is the distance from the same anterior point to the posterior medial angle.

The width of the orbital surface is the distance between the posterior medial angle of the surface and the posterior tip of the malar process.

The nasal width of the palatine process is measured on the superior surface from the median posterior angle to the inner margin of the infraorbital foramen.

## MEASUREMENTS OF TWENTY-FIVE MAXILLARY BONES.

Alveolar length . . . . .	35	33	33	32	32	31	31	31	31	30	30	30	30	30	30	29	29	29	28	28	28
Maximum height . . . . .	37	33	32	32	32	31	31	31	30	29	29	28	28	27	27	26	28	27	28	27	25
Ascending width . . . . .	15	14	13	14	13	14	13	13	12	12	13	11	12	11	12	11.5	12	12	11	10	11
Palatal width . . . . .	17	15	15	14	15	14	16	14	14	15	14	14	14	13	13	14	13	12	13.5	14	13
Malar height . . . . .	12	13	12	13	14	13	14	12	11	12	13	12	12	12	11	10	12	11	13	13	11
Orbital surface:																					
Lateral length . . . . .	23	20	21	20	19	20	22	21	19	19	20	19	20	18	20	19	17.5	18	19	19	18
Medial length . . . . .	18	18	17	18	16	18	18	17	17	17.5	17	18	17	17	17	17	16	16	17	17	16
Width . . . . .	16	15	14	12	14	14	15	14	13	13	14	14	14	12	13	12	13	14	12	15	12
Nasal width . . . . .	15.5	15	15	14	15	14	15	14	13	14	13	13	13	13	13	14	13	12	14	14	12

## VARIATIONS IN FORM AND DEVELOPMENT.

The maxillary presents few and unimportant variations in form. The external surface of the body under the malar process is sometimes much reduced in height; the canine eminence varies in prominence; the lachrymal tubercle may be absent; the nasal surface of the nasal process exhibits variable markings for the attachment of the lateral ethmoid.

The **infraorbital foramen** may be large or small, round or oval. It is not infrequently double; of two hundred and fifty maxillaries examined it was double in twenty,—or twelve and a half per cent. This variation is often, but not invariably, symmetrical.

The **alveolar border** exhibits variations in the number of sockets for the teeth.

One hundred maxillaries (rights and lefts) were studied with reference to this point, with the following results:

The canine alveolus presented no variations.

The first premolar was entirely absent in nineteen; was indicated by one alveolus in forty-three; by two separate alveoli in nine; and by two more or less confluent alveoli in twenty-nine.

The second premolar had two alveoli in eighty-seven; three in nine; and three with the third or internal more or less confluent with the outer posterior, in four.

The third premolar was always implanted in three alveoli.

The small molar was absent in five maxillaries; showed one alveolus in twenty-one; two alveoli in thirty-one; and two more or less confluent in forty-three.

The following table exhibits the manner in which these variations occurred together. The first figure in each case represents the number of alveoli for the first premolar; the second figure, the number for the second premolar, and the third figure, the number for the molar. Confluence (C) in the cases of the first premolar and the molar is between the two alveoli when present, in the case of the second premolar between the abnormal third alveolus and the normal posterior outer alveolus. The figure following the dash is the number of times the combination was found in one hundred maxillaries. Thus 1, 2, C,—12 means that in twelve specimens the first premolar had one alveolus; the second premolar two; and the molar two, more or less confluent.

0, 2, 0,—1	1, 2, 1,—12	2, 2, 2,—5	C, 2, 1,—2
0, 2, 1,—3	1, 2, 2,—11	2, 2, C,—2	C, 2, 2,—7
0, 2, 2,—6	1, 2, C,—12	2, 3, C,—1	C, 2, C,—16
0, 2, C,—6	1, 2, 0,—4	2, C, 2,—1	C, 3, C,—2
0, 3, 1,—2	1, 3, 1,—1		C, C, 1,—1
0, 3, C,—1	1, 3, C,—2		C, C, 2,—1
	1, C, C,—1		

The positions of the alveoli of a tooth may be slightly changed when, as sometimes happens, the tooth is implanted in the jaw obliquely to the long axis of the alveolar border.

In two specimens examined there was no diastema between the first and second premolars.

It is difficult in some instances to distinguish between true variations and such abnormalities as result from disease. Two specimens exhibited changes which may belong to the latter group. In one the lachrymal opening was greatly increased in size, in fact equalling the infraorbital foramen, and led into a large lachrymal canal, in the outer wall of which an opening communicated with the canine alveolus. In the other specimen the body of the maxillary contained a true maxillary sinus which opened by an irregular foramen into the nasal cavity in the fossa between the superior and inferior attachments of the maxillo-turbinal.

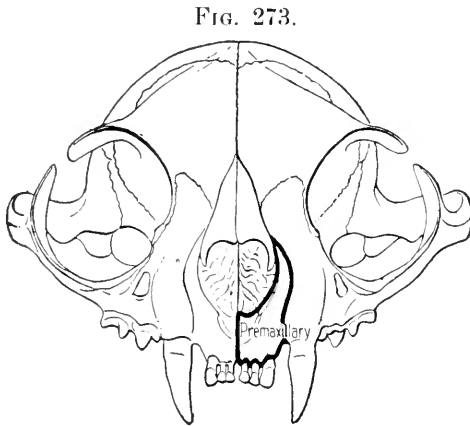
### THE PREMAXILLARY BONES.

**General Description.**—The Premaxillaries are median paired bones, situated at the extreme anterior point of the skull (Fig. 273). They lie on each side of the anterior nasal opening, and form the tip of the upper jaw and complete the front part of the roof of the mouth. In them are implanted the six incisor teeth. Each bone consists of an inferior, thickened portion, the horizontal plate, or **body**, from the upper surface whereof, at the outer part, rises a curved **ascending** or **nasal process**, and from the posterior surface whereof, at the inner side, springs a straight-pointed **palatine process**.

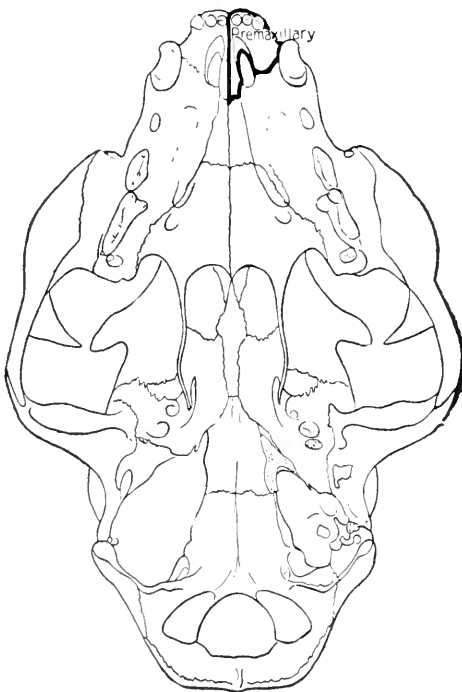
The **Body** is a curved bar, and presents six surfaces.

The **anterior surface** (Fig. 274) is about twice as wide as high, strongly convex from side to side, and slightly concave from above downward, producing the incisive fossa; it faces outward and forward.

Its upper outer part is continuous with the outer surface of the nasal process. Its internal border is straight and vertical, and unites with



FRONT VIEW.



LOWER VIEW.

POSITION OF LEFT PREMAXILLARY BONE.

the corresponding border of the opposite bone. The external border is also straight, vertical, but slightly serrated, and is the anterior border of the external surface, for articulation with the maxillary. The inferior border shows on its inner half three small emarginations, which are the sides of the openings for the incisors on the lower surface, and on its outer half a long faint emargination marking the diastema between the incisors and the canine. The superior border is hardly distinct, inasmuch as the inner half of the anterior surface curves up on the superior surface. At the middle is a tubercle from which springs the anterior border of the nasal process.

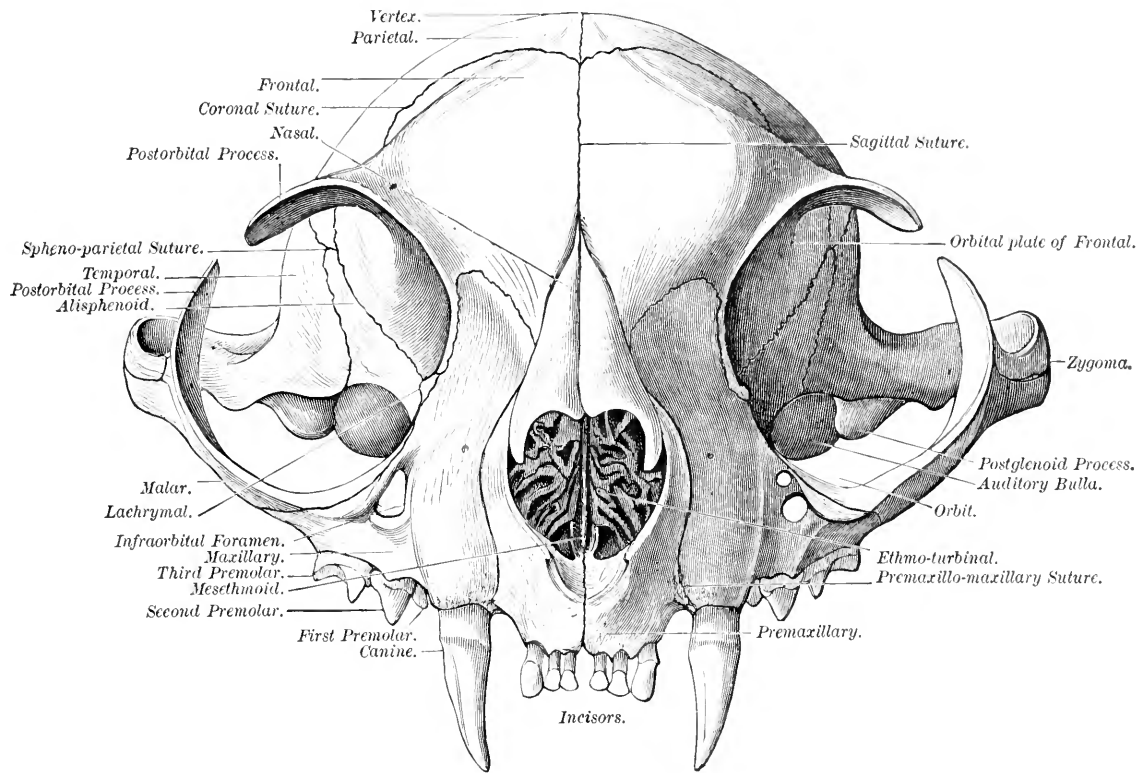
The external surface (Fig. 275) faces outward and backward; it is triangular, the apex pointing upward, and continuous with the posterior border of the nasal process. The anterior border is convex, the posterior concave; the base is straight and slants upward and backward.

The external surface is excavated and rough, and joins the maxillary.

The internal surface (Fig. 278) is flat and continuous with the internal surface of the palatine process. It is quadrate, and longer than high, with the upper anterior angle rounded and the posterior lower border emarginate posteriorly.



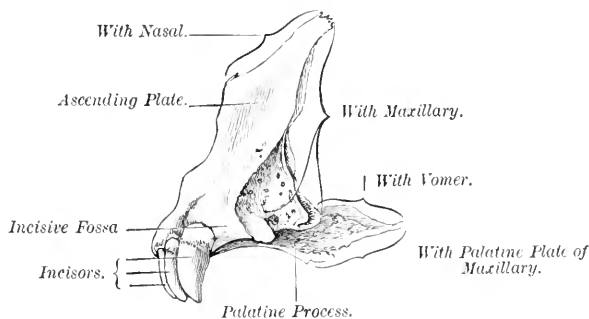
FIG. 274.



SKULL, FRONT VIEW.

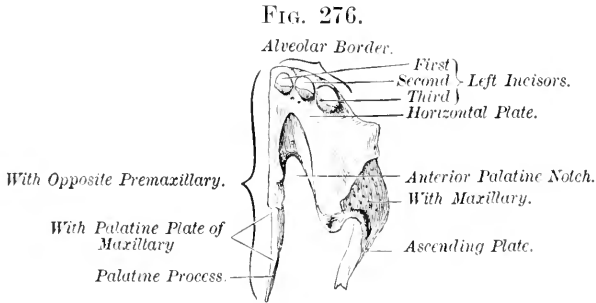
The inferior surface (Fig. 276) is slightly convex. Its long axis is oblique, the anterior and posterior margins are curved; the former is arcuate and the latter is emarginate. The external border is straight and directed backward and inward. The internal border is straight and longitudinal. Its anterior part is called the alveolar border, and its inner half contains the three alveoli for the incisor teeth. These alveoli are oval openings, the long diameters of which are directed

FIG. 275.



LEFT PREMAXILLARY BONE, OUTER SURFACE, SIDE VIEW.

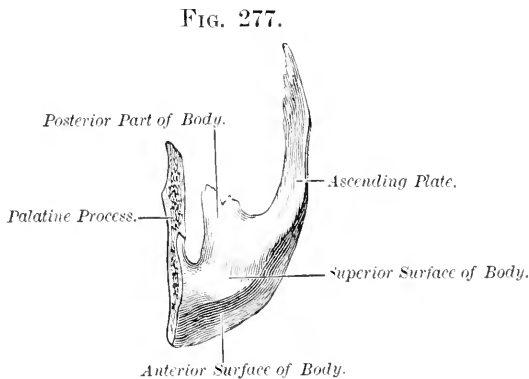
from before backward. They increase in size from within outward. Beyond the alveoli is a somewhat hollow area devoid of teeth, called a diastema. A portion of the lower surface which is bounded in front by a curved line beginning behind the central incisor and passing out-



LEFT PREMAXILLARY BONE, LOWER VIEW.

ward and backward to the posterior external angle is depressed and slopes upward and backward at the expense of the posterior surface, to form the anterior wall of the **anterior palatine notch**.

The **superior surface** (Fig. 277) is of small extent and confined to the inner part of the bone only, because the outer part gives origin to



LEFT PREMAXILLARY BONE, UPPER VIEW.

the nasal process. It forms the lower innermost margin of the anterior nares.

The **posterior surface** is limited in front to the narrow line between the superior surface and the deep emargination on the inferior surface at the front of the palatine notch. At the side it slopes upward, outward, and forward into the internal surface of the ascending plate. A vertical slit in its sharp posterior border receives the edge of the maxillary bone.

The **Ascending Plate**, or **Nasal Process**, is a thin, pointed splint of bone, which rises from the external superior side of the body. It is bowed outward, twisted on its own axis, and points backward as well as upward. It has two surfaces and two borders.

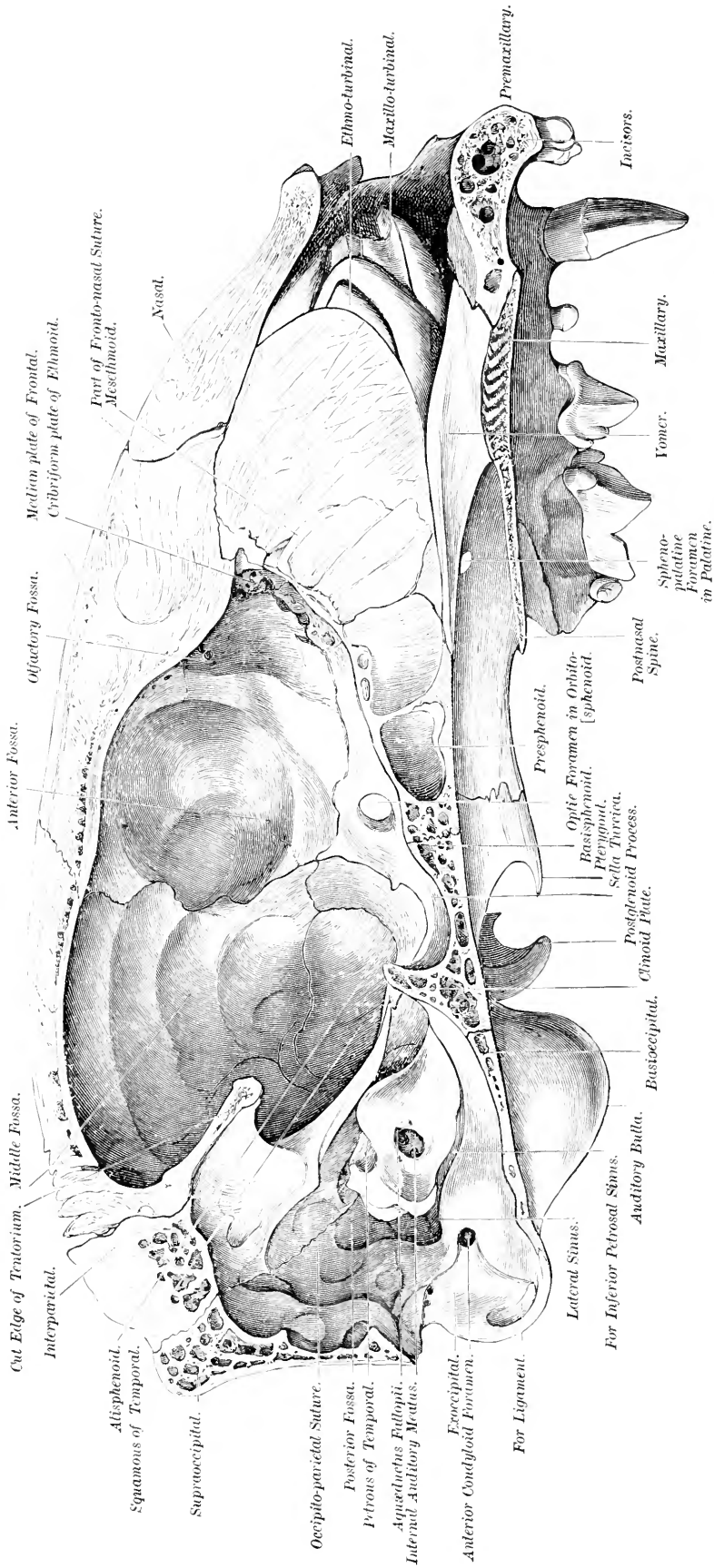
The **external**, or **facial**, **surface** (Figs. 274, 275) is a continuation upward of the anterior surface of the body. It is triangular, convex from above downward, smooth, and forms the lower part of the side of the nose. Near its posterior border, below, is a nutrient foramen. Its anterior border begins in a little spine or tubercle, the **anterior nasal spine**, on the superior border of the body; it then passes upward as the rounded and emarginate lateral margin of the nasal aperture. Above this opening it is straight, cut off obliquely backward, and joins the nasal bone. The posterior border is sinuate, and cleft to receive the sharp anterior edge of the ascending process of the maxillary. The internal surface has the same form as the external, but is concave from above downward. It is smooth, and enters into the extreme anterior part of the lateral wall of the nasal chamber.

The **Palatine Process** (Figs. 276, 277) springs from the inner side of the body; it runs directly backward, and is compressed laterally. The triangular interval left between it and the posterior surface of the body of the bone is known as the **palatine notch**, which, when completed behind by the maxillary, becomes the **anterior palatine foramen**. The lower part of the median surface (Fig. 278) is flat and smooth, and articulates with the same process of the opposite bone. The upper part, which is arcuate above, is also smooth, but slopes slightly outward, forming with its fellow a groove which receives the lower end of the cartilaginous nasal septum. The external surface has the shape of the median surface and is concave from above downward. Its posterior pointed part articulates with the maxillary and with the vomer. The lower border is long and narrow; it contributes one-half of the septum which divides the anterior palatine foramina. The posterior border runs upward and backward and articulates with the superior surface of the horizontal plate of the maxillary.

**Determination.**—When the alveolar border is held uppermost and away from the student, the palatine process is on the side to which the bone belongs.

**Articulation.**—Each premaxillary articulates with the maxillary, the nasal, the vomer, and the other premaxillary.

FIG. 278.



THE SKULL, SIDE VIEW OF CRANIAL AND NASAL CAVITIES.

**Ossification.**—The premaxillary develops from one centre of ossification.

#### VARIATIONS IN THE PREMAXILLARY BONES.

The premaxillary may be measured as follows:

The maximum length is the distance from the anterior edge of the alveolar border to the posterior tip of the palatine process.

The width is the maximum transverse diameter of the inferior aspect, from the median border of the palatine process to the outer edge of the body, at the anterior lower angle of the articular surface for the maxillary.

The length of the body is the distance from the anterior median point of the alveolar border, the so-called **alveolar point**, to the lower posterior angle of the articular surface for the maxillary.

The height is the shortest distance from the posterior angle of the body to the tip of the nasal process.

Length.	Width.	Length of Body.	Height.	Length.	Width.	Length of Body.	Height.
19	9	13	20	16	8	12	17
19	9	12	19	16	7	12	17
18	9	14	18	16	7	10	16
17	9	11.5	19	15.5	8	11	17.5
17	9	10.5	18	15.5	7	11	7
17	8	12	18.5	15	8	11	10
17	8	10.5	17.5	15	7	10	16.5
16.5	9	12	17	15	6.5	10	15
16	9	11	18	14	7	10.5	15
16	9	11	17	14	7	10	15
16	8.5	11	19	13	9	11	17.5
16	8	12	18	13	7	10	13

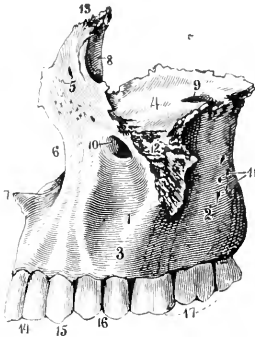
Variations in form appear to be confined to slight differences in the inclination and degree of curvature of the nasal process; in the prominence of the tubercle on the anterior superior border of the body; and in the amount of depression of the external surface.

#### HUMAN MAXILLARY BONES.

Each human maxillary bone includes also the premaxillary of that side of the skull; although the premaxillary arises from a separate centre of ossification, it coalesces so quickly with the maxillary that its independent origin can be hardly recognized.

The maxillary differs from the united maxillary and premaxillary of the cat in being extremely short (Figs. 279, 280); the body,

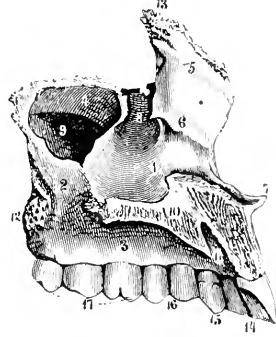
FIG. 279.



LEFT MAXILLARY, OUTER VIEW.

1, body; 2, tuberosity; 3, alveolar process; 4, orbital plate; 5, nasal process; 6, nasal notch; 7, nasal spine; 8, lachrymal groove; 9, entrance of the infraorbital canal; 10, infraorbital foramen; 11, orifices of the posterior dental canals; 12, malar process; 13, articulation for the internal angular process of the frontal bone; 14, incisor teeth; 15, canine tooth; 16, premolar teeth; 17, molar teeth.

FIG. 280.



LEFT MAXILLARY, INNER VIEW.

1, nasal surface of the body; 2, surface for the palate bone; 3, alveolar process; 4, orbital plate; 5, nasal process; 6, ridge for the articulation of the maxillo-turbinal bone; 7, nasal spine; 8, lachrymal groove; 9, antrum; 10, palatine process; 11, anterior palatine fossa; 12, tuberosity; 13, articular extremity for the internal angular process of the frontal bone; 14, incisor teeth; 15, canine tooth; 16, premolar teeth; 17, molar teeth.

however, is very high and encloses a large cavity, the **antrum** of Highmore,<sup>1</sup> or maxillary sinus, which opens widely on the nasal surface (Fig. 280).

The orbital surface (Fig. 279) is elevated far above the alveolar margin, and is not prolonged backward beyond the posterior limit of the palatine process. With the malar it forms the bony floor of the orbit, which ends behind, where the smooth and rounded margin of the surface becomes the anterior border of the superior orbital, or spheeno-maxillary, fissure (Fig. 281). A small portion of the anterior border between the lachrymal canal on the inside and the malar articular surface on the outside assists in the formation of the inferior orbital rim; in the cat, the malar by uniting with the lachrymal excludes the maxillary from this part of the orbital rim. The **infra-orbital groove** begins at the posterior border, runs forward, and enters the **orbital canal**, which passes through the bone and terminates in front and below at the infraorbital foramen.

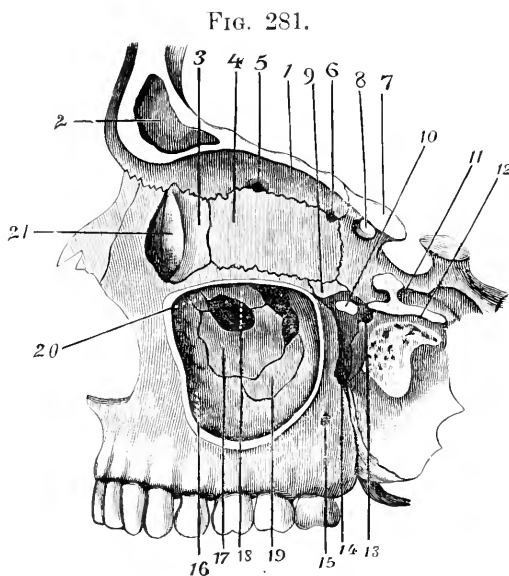
The posterior surface of the body is also termed the zygomatic surface, since it faces the zygomatic fossa. It is convex, rounded, and pierced near the middle by the **posterior dental foramina**; its lower

<sup>1</sup> Highmore (A.D. 1613-1684).

angle forms the **tuberosity**. On the lower part of the inner border is a rough area for the tuberosity of the palatine bone; above which is a groove forming a part of the posterior palatine canal. At the end of the inner border of the orbital surface is an area for articulation with the ethmoidal process of the palatine bone (Fig. 281).

The high **external, or facial, surface** exhibits a deep **canine fossa** under the **infraorbital foramen**. The premaxillary margin of the nasal aperture presents a well-marked median **nasal spine**.

The **nasal surface** of the body (Fig. 280) is much larger than the corresponding surface of the cat's maxillary, and the short ridge for



LEFT SIDE OF FACE, OUTER WALLS OF THE ORBIT AND ANTRUM REMOVED.

1, frontal orbital plate; 2, frontal sinus; 3, lachrymal bone; 4, ethmoid bone; 5, 6, ethmoidal foramina; 7, sphenoid bone; 8, optic foramen; 9, palatine bone, ethmoidal process; 10, sphenopalatine foramen in inner wall of sphenomaxillary fossa; 11, foramen rotundum; 12, Vidian canal; 13, pharyngeal canal; 14, termination of the pterygo-maxillary fissure in the posterior palatine canal; 15, posterior dental canal; 16, inner wall of the antrum formed by the maxilla; 17, maxillo-turbinal bone; 18, uncinate process of the ethmoid; 19, palatine bone; 20, descending process of the lachrymal behind which is the opening of the antrum into the nasal cavity; 21, lachrymal fossa.

the maxillo-turbinal is high above the origin of the palatine process. The posterior half of the surface is wanting at the point where the antrum opens into the nasal cavity.

The **inferior, or alveolar, border** is so prominent that it has been called the **alveolar process**. In it are implanted eight teeth,—namely, two incisors, a single canine, two premolars, and three molars.

The **nasal process** is small; its nasal surface presents a **superior turbinated crest** for articulation with the middle turbinated bone of

the lateral ethmoid; its posterior border is wide and occupied by the lachrymal groove.

The palatine process is attached to the body at a right angle; it is not horizontal, however, but arches from the front upward and backward, so that its posterior part is much above the alveolar border. Its inferior surface is pierced by small vascular foramina, and is usually separated from the adjoining surface of the body by a groove for the anterior palatine nerve and the posterior palatine vessels.

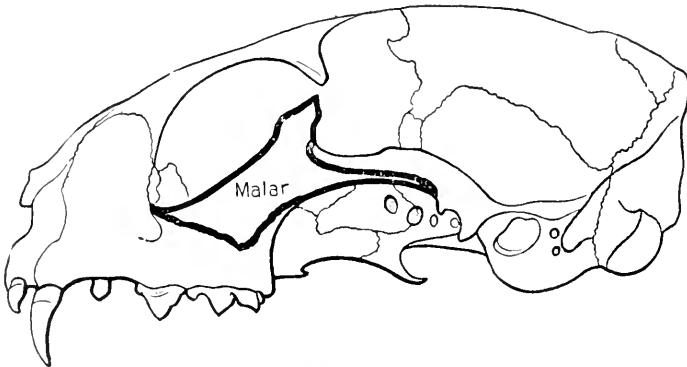
The two anterior palatine foramina together constitute the anterior palatine fossa, which contains four passages, whereof the two lateral and larger, known as Stenson's<sup>1</sup> canals, lodge mucous membrane and the remnants of Jacobson's organs; the two median passages, the foramina of Scarpa,<sup>2</sup> are arranged one in front of the other and transmit the naso-palatine nerves.

The malar process is triangular, and, with its ridge-like downward prolongation, separates the facial from the zygomatic surface.

#### THE MALAR BONES.

**General Description.**—The Malars form the bony cheeks and the anterior half of the zygomatic arches which connect the sides of the face with the cranium (Fig. 282); they therefore form the entire

FIG. 282.



POSITION OF LEFT MALAR BONE. SIDE VIEW.

outer walls of the orbits and portions of the outer boundaries of the zygomatic fossæ.

Each malar is a thin, somewhat quadrilateral band, whereof the posterior-inferior angle is produced into a slender process, and the

<sup>1</sup> Stenson (A.D. 1638–1687).

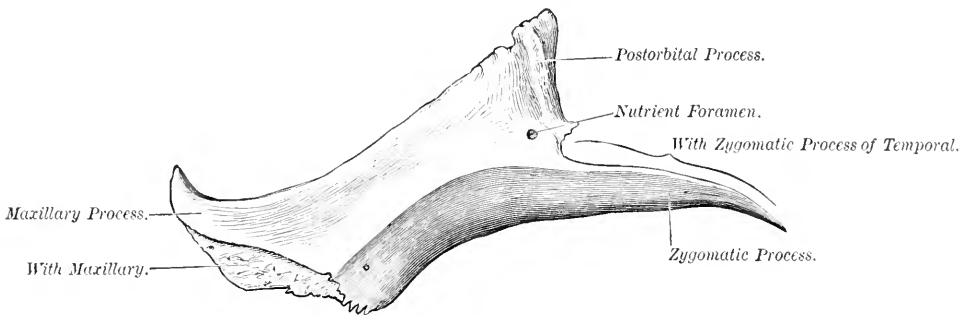
<sup>2</sup> Scarpa (A.D. 1747–1832).



anterior-superior angle is prolonged obtusely. Inasmuch as the superior angles are bent inward, the bone appears to be bowed strongly outward. The malar presents two principal surfaces, four borders, and three processes.

The **external**, or **facial**, **surface** (Fig. 283) faces downward and outward. It has the general shape of the bone, and is bounded above

FIG. 283.



LEFT MALAR, OUTER SURFACE.

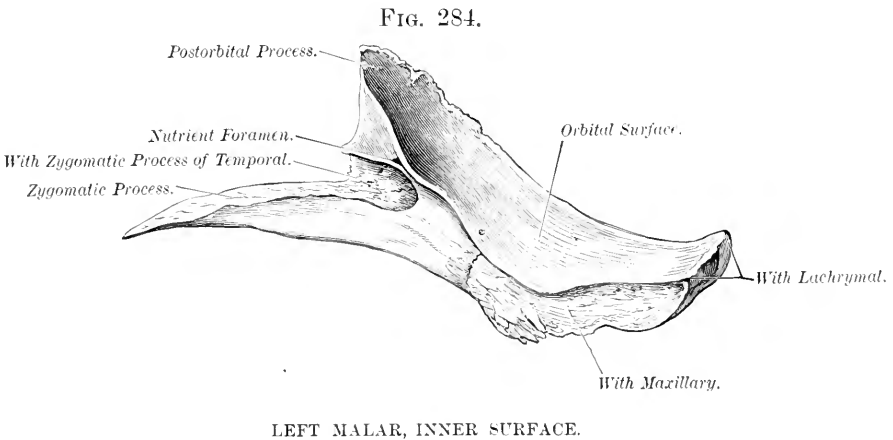
by the orbital and temporal borders; behind by the temporal border; below by the inferior, or zygomatic, border; and in front by the anterior, or maxillary, border. It is divided into two parts by a prominent masseteric ridge which arches upward and backward from about the middle of the anterior border to the notch between the two prominent posterior corners. The larger part, above this ridge, is convex from before backward, and slightly concave from side to side. Its curved, forward prolongation is called the **maxillary process**, and the posterior extension is called the **postorbital**, or **frontal**, **process**, and is sometimes united to a similar process projecting from the frontal, thus forming a posterior boundary to the orbital rim. The part of the external surface below the dividing ridge is flat and faces downward and backward, and is continued posteriorly as the slender **zygomatic process**. It gives origin to fibres of the masseter.

The **orbital border** is strongly bowed outward. Through most of its length it is sharp and slightly serrated and is the outer margin of the orbit. Its anterior end is at first rounded and then bevelled forward and downward toward the external surface, to form a small triangular anterior surface.

The **maxillary border** is rough and bevelled on each side, and fits into the curved cleft in the malar process of the maxillary.

The **zygomatic border** is sharp and slightly emarginate. It is continued backward as the lower margin of the zygomatic process.

The **postorbital process** is stout and triangular; it curves inward and its apex is directed upward and backward. Its anterior border is continuous with the orbital border of the bone. Its posterior border meets the upper or temporal border of the zygomatic process at a right angle, but is usually separated from it by a **marginal spine** at the upper edge of a notch which is more or less deep. The outer surface (Fig. 283) is smooth or subcutaneous. On it, near the base of the process, is a more or less constant foramen, sometimes called the **malar canal**. The inner surface (Fig. 284) is divided into orbital and



temporal surfaces by a prominent **orbital crest** which passes from the apex obliquely down to the rough surface for the maxillary near the anterior-inferior angle. The apex is sometimes truncated and connected with the postorbital process of the frontal.

The **zygomatic process** is a curved prolongation of the posterior-inferior angle. Its outer surface is smooth, and the inner surface (Fig. 284) is roughened along its upper half for the attachment of the zygomatic process of the temporal.

The **maxillary process** (Fig. 283) is a hook-like extension of the anterior-superior angle. Its apex articulates with the lachrymal bone.

The **inner surface** of the malar (Fig. 284) is largely occupied by the smooth **orbital surface**, which begins in front on the inner side of the maxillary process as a narrow strip, then widens so as almost to reach the zygomatic border, and then narrows again and forms the orbital surface of the postorbital process. It is concave from before

backward. The rest of the inner surface consists of two parts: a triangular roughened anterior and lower part, behind the anterior border, articulating with the maxillary bone; and a narrow non-articular zygomatic strip, under the orbital surface, and continued on the zygomatic process, under the articular surface for the temporal.

**Nomenclature.**—Malar comes from the Latin *mala*, the cheek-bone, or cheek. The synonyms *os zygomaticum* and *os jugale* are derived from the Greek and Latin words *zygoma* and *jugum*, meaning a yoke. The French use *l'os malaire* and *l'os zygomatique*, and the Germans *das Joehbein* and *das Wangenbein*.

**Determination.**—If the malar be held with the postorbital process uppermost and the inner surface toward the student, the slender zygomatic process will be on the side to which the bone belongs.

**Articulation.**—The malar articulates with the lachrymal, the maxillary, the temporal, and sometimes with the frontal.

**Muscular Attachments.**—The malar gives attachment to the temporal, masseter, and zygomatic muscles.

**Ossification.**—The malar is developed from a single centre of ossification.

#### VARIATIONS IN THE MALAR BONES.

##### VARIATIONS IN SIZE.

The following are the measurements taken on twenty-five left malar bones:

The length is the shortest distance from the tip of the maxillary process to the end of the zygomatic process.

The orbital length is the shortest distance from the tip of the maxillary process to the tip of the postorbital process.

The height of the postorbital process is the length of its posterior border.

The maximum height of the bone is the distance from the tip of the postorbital process along its posterior border across the root of the zygomatic surface to the lower margin of the bone.

The orbital height is the diameter of the body of the bone at its narrowest part and transverse to the masseteric ridge.

Length.	Orbital Length.	Postorbital Height.	Height.	Orbital Height.
46	30	13	17	12
44	30	14	16	11
43	33	12	18	12
43	30	13	17	13
42	29.5	11	15.5	11
42	29	11	15	10
41	27	11	15	11
40	29	10.5	13	10.5
40	28	10	13	11
40	26	10	13	11
39	29.5	12.5	15	10.5
39	28	13	16	12
39	27	9.5	13	11
39	27	9	12	10
39	27	8	12	9
38	27	11	15	10
38	26	10	13	9
36	26.5	12	16	11
36	26	11	14	9
36	26	10	14	9
36	25.5	8	11	9
35	27	11	14	10.5
35	27	9	11	10
34	27	11	14	10
34	24	8	11	10

#### VARIATIONS IN FORM AND DEVELOPMENT.

On the **outer surface** the masseteric area below the curved line may be much greater than the area above the line.

On the inner aspect the **orbital surface** in some specimens extends almost to the lower border, in others it may be relatively very narrow.

Not infrequently the **postorbital process** is so flattened that the inner surface exhibits no orbital crest. Its tip varies; it may be acutely pointed or broad and rough.

The **malar canal** may be absent, or merely groove the posterior postorbital border; it may be double. Its inner opening is found on or near the orbital crest.

The **zygomatic process** varies in length; in some specimens its end is hooked and spatulate.

#### HUMAN MALAR BONES.

In the human skull the distance from the end of the zygomatic process of the temporal to the maxillary bone is so short that the intervening malar bone has assumed an almost square outline (Fig. 285).

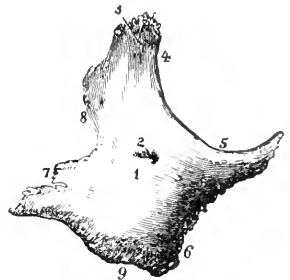
The smooth convex **external**, or **facial**, surface is bounded by the orbital, maxillary, zygomatic, and temporal borders, and is prolonged on the maxillary, zygomatic, and postorbital, or frontal, processes.

In some specimens the external surface exhibits in front of the middle a marked swelling, the **malar tuberosity**; and the temporal margin of the frontal process may be enlarged at one point, to form a **marginal process** for the stronger attachment of the temporal fascia.

The **internal surface** of the malar is divided into two parts by a strong plate, which begins at the apex of the frontal process, ends below at the maxillary articular surface, and is directed inward. This plate is named the **orbital process**, and corresponds to the crest on the inner surface of the postorbital process of the cat's malar. Its **upper margin** is continuous with the end of the frontal process, and with it joins the external angular process of the frontal bone; its **inner margin** joins the malar crest of the large wing of the sphenoid, except at a small point below, where it forms the rounded anterior border of the spheno-maxillary fissure.

In the cat, the orbital and temporal parts of the inner surface lie almost in the same plane; in man, the orbital surface faces forward and inward and forms the anterior part of the side wall of the orbital cavity, while the temporal part is deeply concave, faces inward and backward, and in part forms the anterior and external walls of the temporal and zygomatic fossæ.

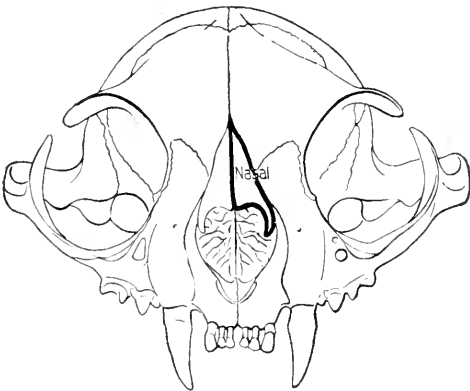
FIG. 285.



RIGHT MALAR BONE, OUTER VIEW.

1, external or facial surface; 2, malar foramen; 3, frontal process; 4, 5, orbital border; 6, maxillary border; 7, zygomatic process; 8, temporal border; 9, zygomatic border.

FIG. 286.



POSITION OF LEFT NASAL BONE. FRONT VIEW.

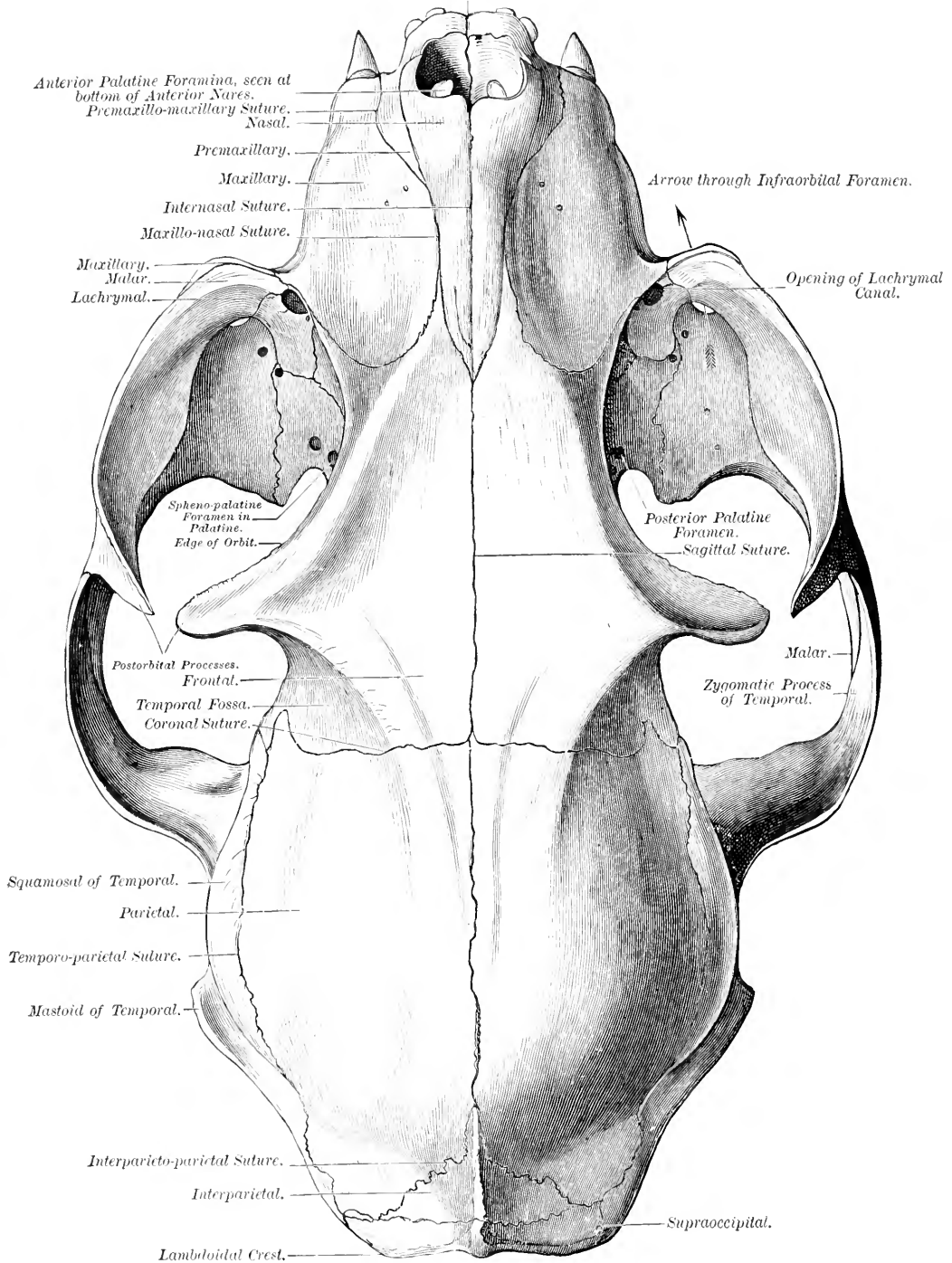
## THE NASAL BONES.

### General Description.—

The Nasals are two long narrow bones which lie side by side at the anterior end of the skull just above the nasal aperture (Fig. 286).

FIG. 287.

*Interpremaxillary Suture.*

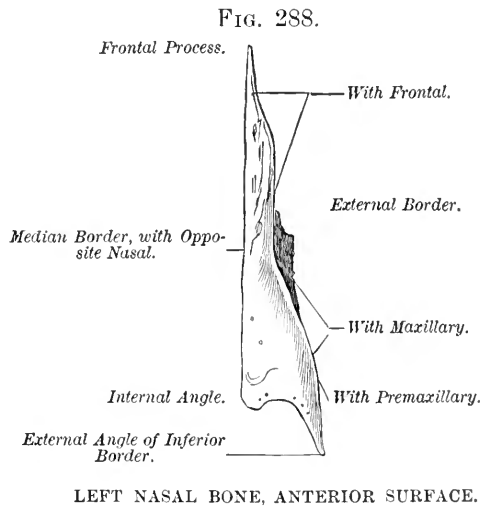


THE SKULL, FROM ABOVE.

Together they form a wedge which separates the nasal processes of the frontals, and the upper ends of the nasal processes of the maxillaries and premaxillaries. They contribute the greater part of the front wall of the nasal chamber and all of the superior margin of the nasal aperture.

Each bone has four surfaces, an anterior, a posterior, an external, and an internal, and a superior and an inferior border. Inasmuch as the bone is compressed at its lower end from above downward and at its upper end from side to side, the inferior border is directed from side to side and the superior border is directed from in front backward. All four surfaces are triangular, the anterior and posterior with their apices superior, the external and internal with their apices inferior.

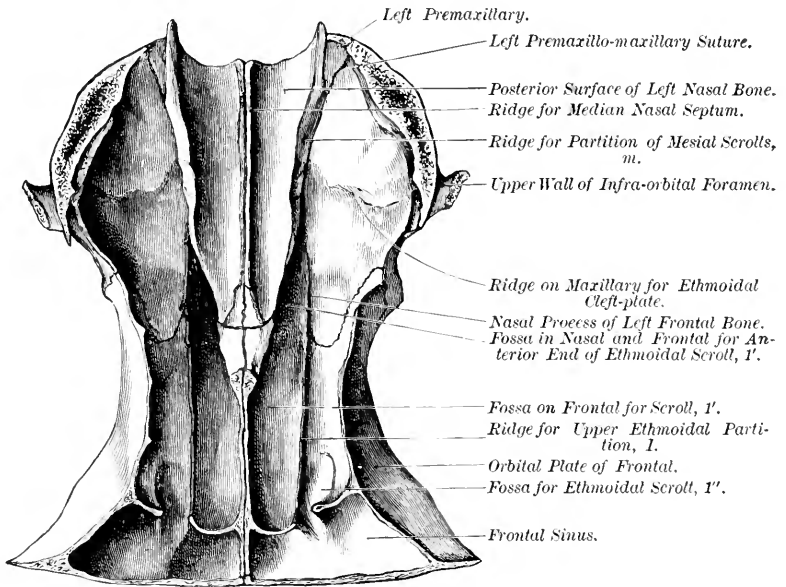
The **anterior surface** (Fig. 288) is the only part of the bone which is visible on the exterior of the skull. It is triangular; its length is about four times greater than the width at the base. The inferior-external angle is produced downward in a long, blunt, and slightly curved **external nasal process**. The external posterior border of this process is applied to the front of the premaxillary, and the inner border forms part of the boundary of the nasal aperture. The inferior border of the external surface between the base of this process and the inner angle is sharp, and slightly emarginate. The inferior-internal angle is sometimes slightly prominent, and sometimes forms with the angle of the opposite bone a faint superior **median nasal spine**, to which the median cartilaginous septum of the external nose is attached. The internal or median border is straight and joins the opposite bone; the superior extremity of the internasal suture marks the point on the skull known as the **nasion**. The external border is sinuate and directed downward and outward. In its upper and lower thirds it is arcuate, and in the middle third emarginate; it joins the borders of the nasal processes of the frontal, maxillary, and premaxillary bones (Fig. 287).



The anterior surface faces upward and forward, and is convex from side to side, more especially in the lower part. It is convex from above downward in its narrower upper two-thirds, and flattened in its widest part below. Small foramina for the transmission of vessels are often present near the middle of the inner border, and on the outer border at about the junction of the middle and lower thirds.

The posterior surface of the nasal bone (Fig. 289) has the shape of the external surface, but is shorter and, above, encroached upon by

FIG. 289.



ROOF AND PART OF ANTERIOR WALL OF NASAL CHAMBER; ETHMOID REMOVED.

the superior border. Its inferior margin is also the inferior margin of the external surface. The median border is straight, sharp, and elevated, and forms, with the contiguous border of the other nasal, the **nasal crest**, whereto is attached a part of the front of the inter-nasal bony and cartilaginous septum. The external border, which is nearly straight and directed obliquely downward and outward, is high and somewhat rolled inward. It is usually broader below. It abuts for the larger part of its length against the edge of the mesial partition of the inner surface of the lateral ethmoid (Figs. 290, 291). The posterior surface is deeply concave from side to side, forming a curved roof for the anterior part of the nasal chamber and arching over the front of the lateral ethmoid.

The **internal** or **median surface** (Fig. 291) is perfectly flat and

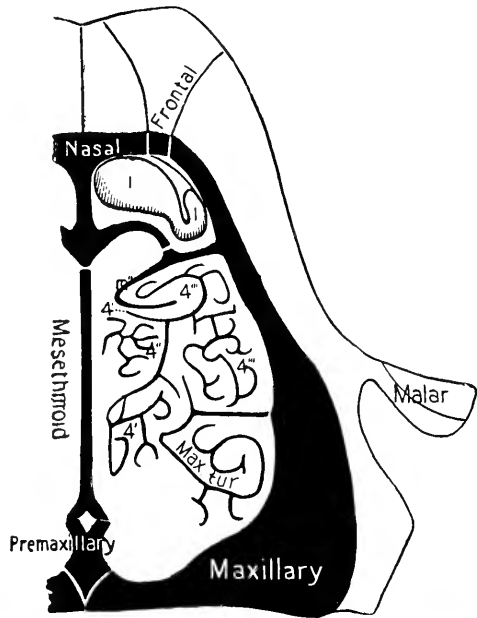


slightly roughened for articulation, throughout its extent, with the opposite bone. It is triangular, but the inferior angle, or apex, is truncated and rounded posteriorly. The superior part, or base, is arcuate, especially behind, following the outline of the convex superior border. The anterior margin is sinuate, slightly arcuate above, and emarginate below. The posterior margin is emarginate above and arcuate below; it enters into the formation of the nasal crest.

The external surface (Fig. 292) is the most complicated. Its shape is about that of

the inner surface; it is more pointed, however, at the lower end, where it is continued as the outer margin of the external angle. The upper half, or more, is occupied by a flat, oval, ethmoidal fossa. The lower half is narrow and largely the outer part of the outer margin of the posterior surface, which is rolled downward. The ethmoidal fossa is limited above by a crescentic rough space, which, with the upper half of the sharp anterior margin, articulates with the median surface of the nasal process of the frontal. The posterior margin begins at the posterior lower end of this crescentic space and passes downward, becoming gradually higher and rolling backward at the lower end; it leaves between the edge of the fossa and the edge of the bone a shelving smooth surface. The fossa is extended into the interior of the bone to a greater or less degree. The inner, upper anterior scroll of the lateral ethmoid (Fig. 290) is contained in this fossa, and a plate lying below it, the partition of the mesial scroll (m), is attached to the posterior margin of the surface, almost down to the angular

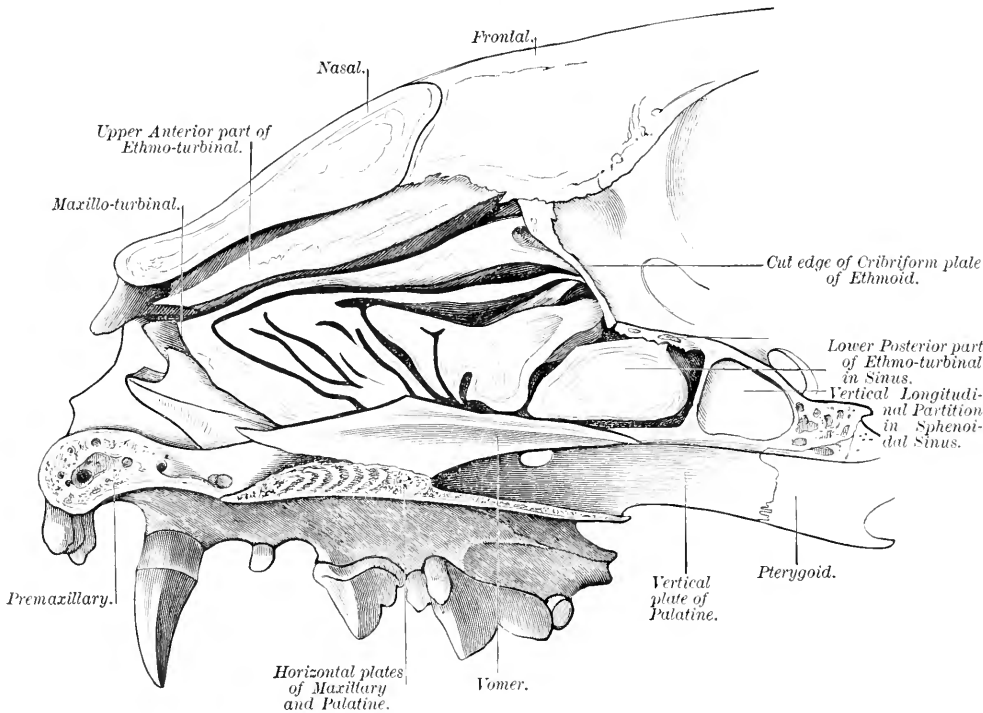
Fig. 290.



TRANSVERSE VERTICAL SECTION THROUGH HALF OF FACE.

Five millimetres anterior to Infraorbital Foramen. Cut surfaces black. (Somewhat diagrammatic.)

FIG. 291.



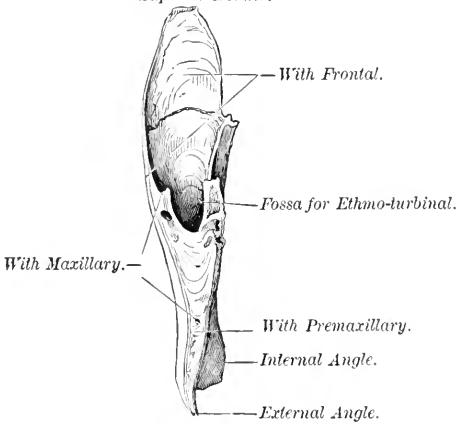
RIGHT NASAL CHAMBER, SIDE VIEW FROM WITHIN.

process. To the lower half of the anterior margin of the fossa and to a part of the anterior edge of the remaining lower half of the internal

surface itself, there is articulated the front border of the nasal process of the maxillary. The lower part of the surface is overlapped by the nasal process of the premaxillary.

**Nomenclature.**—Nasal is from the Latin *nasus*, the nose. *Os nasale* and *os nasi* are also much used. The French equivalents are *l'os nasal* and *l'os propre du nez*. The Germans employ *das Nasenbein*.

FIG. 292.  
Superior Border.



LEFT NASAL BONE, OUTER SURFACE, SIDE VIEW.

**Determination.**—If the bone be held with the anterior surface uppermost and the lower wider part away from the student, the

produced external angle will be on the side to which the bone belongs.

**Articulation.**—The nasals articulate with the premaxillaries, the maxillaries, the frontals, and the ethmoid, and support the cartilage of the external nose.

**Ossification.**—The nasal develops from one centre of ossification.

#### VARIATIONS IN THE NASAL BONES.

##### VARIATIONS IN SIZE.

In the following table are given the measurements of twenty-five left nasal bones :

The median length is the maximum length of the median surface.

The lateral length is the maximum length of the outer surface, including the angular process.

The width is the maximum transverse diameter of the anterior surface.

The lateral width is the maximum antero-posterior diameter of the outer surface.

The length of the ethmoidal fossa is the distance from the superior border of the bone to the superior border of the true fossa.

Median Length.	Lateral Length.	Width.	Lateral Width.	Length of Fossa.
29	32	7	9	19
26	29	6.5	9	14
25	29	6	8	15
25	27.5	6	9	16
25	27	6	8	15
24.5	28	7	10	18
24	27	6	7	14
23	27.5	7	9	15
23	27	6	8	15.5
23	26.5	6.5	7.5	14
22	26	6	7.5	12
22	26	5.5	7	15.5
22	25	6	9	15
22	25	5	6	14
21	25	6	8	12
21	25	6	7	13
21	25	6	7	11
20	25	7	8	11
20	24	6	8	11
20	24	5.5	8	11
20	24	5	8	12
20	23	6	8	9
20	21	6	6	11
19	22	6	7	10
19	22	6	6	10

## VARIATIONS IN FORM AND DEVELOPMENT.

The nasal bone presents many variations in form, and these may be regarded as modifications of several distinct types.

We find flattened bones, in which the anterior surface is only slightly curved above and the posterior median border is almost straight; strongly curved bones, in which the anterior surface is boldly arched almost to the inferior border and the posterior margin is deeply emarginate; short, broad bones; long, narrow bones, and bones in which the diameters retain their normal relative proportions, irrespective of their actual lengths.

The **superior border** exhibits all varieties of outlines, except the emarginate; it may be transversely truncate; obliquely truncate behind; gently and evenly arcuate; obliquely rounded in front or behind, or produced to a sharp point.

The lower **median angle** of the external surface is, in some specimens, so prominent that it forms with its fellow of the opposite bone an obtuse superior nasal spine; in other specimens it is truncated. In the latter case the superior border of the nasal aperture is almost straight.

Not infrequently the external inferior angle of the bone is so broad that it presents a short, sharp, inferior border, which is directed from below obliquely upward and outward.

The variations in the length of the ethmoidal fossa are shown in the preceding table.

**HUMAN NASAL BONES.**

The **external or facial surface** of the nasal bone of man (Fig. 293) is transversely more convex than the corresponding surface on the nasal of the cat; it is more deeply concave from above downward, and faces laterally as well as forward and upward. It presents near the middle a variable venous **nasal foramen**.

The **internal or nasal surface** is deeply concave transversely, and faces in great measure inward. It is traversed near the outer border by a **groove** for the nasal branch of the fifth cranial nerve.

The **superior border** is so broad that it might be termed a roughened surface; it articulates in the nasal notch of the frontal bone.

The **inferior border** is thin, and affords a line of attachment for

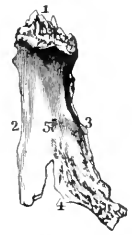
the nasal cartilage; it is sometimes notched at the inferior end of the groove on the nasal surface.

The **external border** is bevelled at the expense of the anterior surface, and is overlapped by the anterior edge of the nasal process of the maxillary.

The **internal or medial border** is prolonged backward, forming a crest to which are attached the nasal spine of the frontal and the anterior border of the mesethmoid and its cartilage.

The **inferior medial angle** forms with its fellow on the other nasal a variable **nasal spine**, or **nasal angle**.

FIG. 293.

LEFT NASAL BONE,  
ANTERIOR VIEW.

1, frontal border; 2, nasal border; 3, maxillary border; 4, inferior border; 5, nasal foramen.

### THE LACHRYMAL BONES.

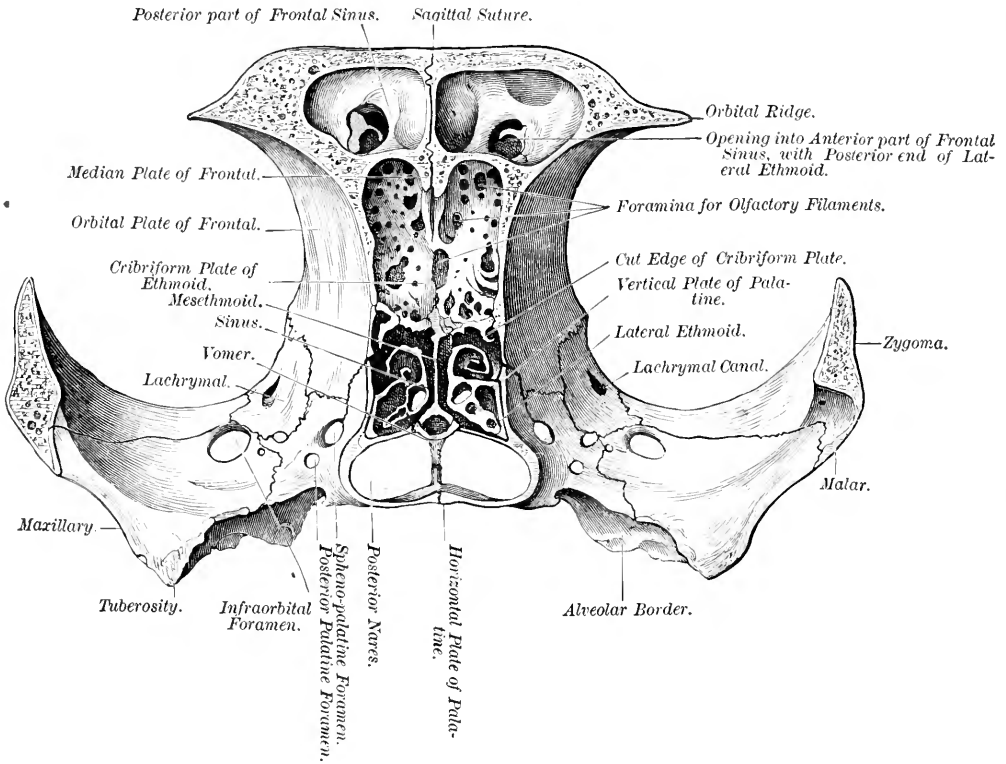
**General Description.**—The Lachrymals are thin bones lying at the inner, lower corners of the orbits (Fig. 294). Each is merely a small plate, about as thin as stiff paper. The shape is usually square, but may vary when encroached upon by the surrounding bones. The lachrymal presents two surfaces and four borders.

The **external or orbital surface** (Fig. 295) is gently concave in all directions. Its **anterior border** is nearly straight, prominent, and everted, and, when the bone is in position, directed upward and slightly backward. Its upper end is prominent, and articulates with the lachrymal tubercle of the maxillary, or itself produces the tubercle; the entire border articulates with the posterior border of the ascending plate of the maxillary. Its **superior or frontal border**, which is irregular and serrated, faces backward and upward and joins the anterior part of the lower border of the orbital plate of the frontal. The anterior-superior angle, where the lachrymal meets the maxillary and frontal bones, marks the point on the skull known as the **dacryon**.<sup>1</sup> The os planum of the lateral ethmoid, when uncovered by a deficiency in the surrounding bones, appears above and behind this border, between the lachrymal, frontal, and palatine. The **posterior border** is straight, faces downward and backward, and articulates with the anterior part of the vertical plate of the palatine. The **inferior border** is slightly emarginate and rounded; it faces downward and somewhat forward and joins the crest of the maxillary, which separates

<sup>1</sup> (Gr.) a tear.

the orbital surface from the superior surface of the palatine plate. Just behind and parallel to the anterior border is a deep and wide vertical groove, the **lachrymal groove**, which lodges the lachrymal duct and is

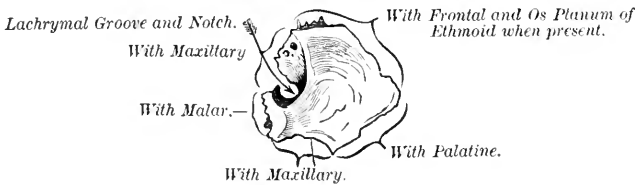
FIG. 294.



TRANSVERSE VERTICAL SECTION OF SKULL THROUGH ORBITS, SEEN FROM BEHIND.

the beginning of the lachrymal canal. Several foramina are to be seen in the upper part of the groove. The groove is separated from the rest of the orbital surface by the **lachrymal crest**, the lower end

FIG. 295.



LEFT LACHRYMAL BONE, OUTER SURFACE.

of which curves upward to form the upper root of the **hamulus**, or hook, a small blunt process arising from the orbital surface just behind and above the anterior-inferior angle and articulating with the lach-

rymal process of the malar. The upper edge of this process is emarginate and known as the **lachrymal notch**. The lachrymal groove passes between the base of this process and the anterior-inferior angle of the bone, and thus divides the lower border in front into two parts.

The **internal** or **nasal** surface of the lachrymal is flat and forms part of the lateral wall of the nasal cavity, especially that region opposite the ethmoidal cleft, which is the outer wall of the middle nasal meatus. Its anterior border is bevelled and overlaps the maxillary; its anterior-inferior angle joins the maxillo-turbinal swelling on the inner surface of the maxillary which contains the lachrymal duct, and also joins the end of the ethmoidal cleft plate, the rudimentary uncinat process. Above the angle a notch completes the lachrymal opening. Close to the posterior border is attached the posterior edge of the plate bounding the ethmoidal cleft of the lateral ethmoid.

**Nomenclature.**—Lachrymal is from the Latin *lachryma*, a tear. *Os lacrimale*, *l'os lacrimal*, and *das Thränenbein* all express the same relation to the tear-duct. *Os unguis* and the French *l'unguis* are from the Latin *unguis*, a finger-nail, owing to the thin, scale-like character of the bone.

**Determination.**—When the smooth concave surface is held uppermost, the hamulus toward the student and the groove directed away from the student, the groove is on the side to which the bone belongs.

**Articulation.**—The lachrymal articulates with the frontal, the maxillary, the malar, the palatine, the ethmoid, and the maxillo-turbinal.

**Muscular Attachments.**—To the lachrymal tubercle are attached the orbicularis palpebrarum and the levator labii superioris.

**Ossification.**—The lachrymal is developed from one centre of ossification.

#### VARIATIONS IN THE LACHRYMAL BONES.

The size of the lachrymal may be roughly measured by taking the greatest antero-posterior diameter and the length of the anterior border. These measurements vary as follows: 14, 10; 12.5, 8; 12, 10; 12, 9; 11, 10; 11, 9; 11, 8; 10.5, 8; 10, 9; 9.5, 10; 9.5, 9; 9, 9; 9, 8; 9, 7; 8, 10; 8, 8; 8, 7.5; 7, 8; 7, 7. Beyond differences in size and shape, which are in part dependent upon the degree of de-

velopment of the surrounding bones, and especially of the os planum of the ethmoid, the lachrymal exhibits few noteworthy variations.

In some specimens the anterior-superior angle is prolonged upward into a long spine, the swollen lip of which forms the greater part of the lachrymal tubercle.

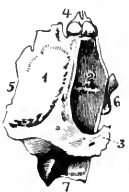
The lachrymal groove is rarely only faintly marked. It is usually perforated by two or three foramina in the upper part and by one or two in the root of the hamulus below; it may be, however, irregularly cribriform.

In one lachrymal examined the anterior border was joined to the hamulus, producing a true lachrymal foramen. The hamulus itself may be thin or thick; the malar surface is, therefore, sometimes linear, sometimes quadrate.

#### HUMAN LACHRYMAL BONE.

The lachrymal bone of man (Fig. 296) is almost identical with the lachrymal of the cat. It differs from the latter in being relatively narrower from before backward, in not articulating by its anterior-inferior angle with the malar, and in articulating behind with the constant os planum of the ethmoid, and on the inside more distinctly with the lachrymal process of the maxillo-turbinal and the uncinat process of the lateral ethmoid. Its internal surface completes the so-called lachrymal cells of the ethmoid.

Fig. 296.



RIGHT LACHRYMAL BONE. EXTERNAL VIEW.

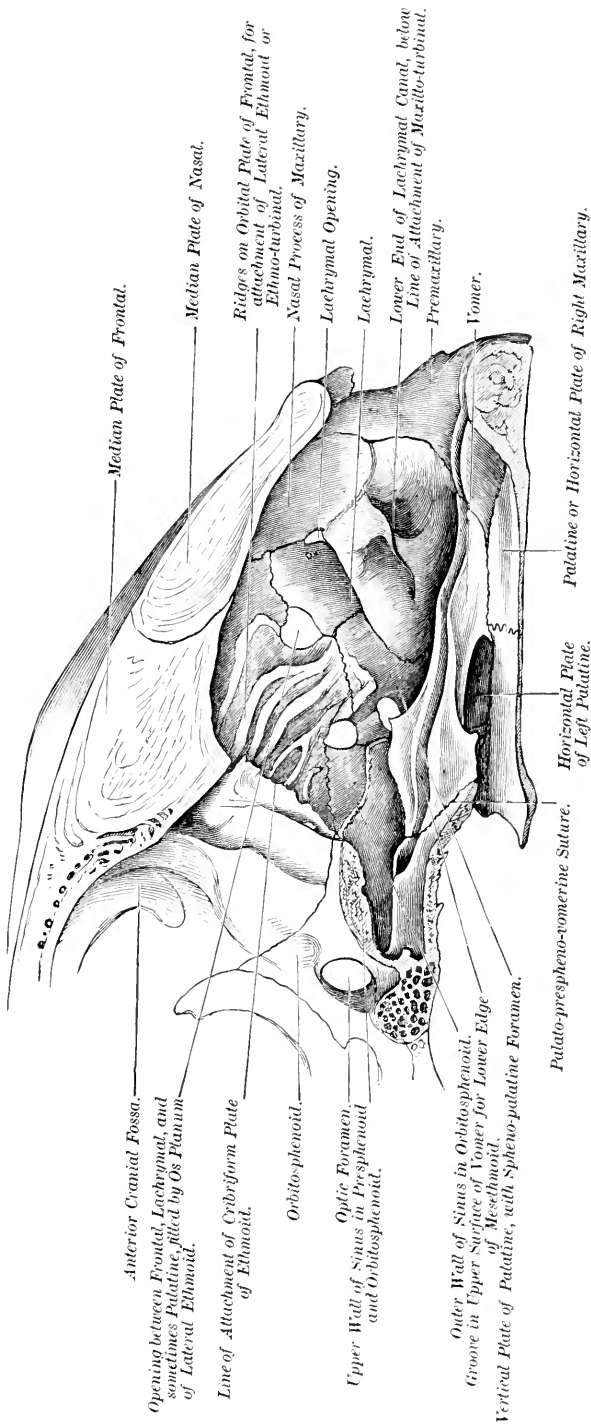
- 1, orbital surface;
- 2, lachrymal groove;
- 3, hamulus; 4, frontal border; 5, ethmoidal border; 6, maxillary border; 7, process articulating with the maxillo-turbinal bone.

#### THE VOMER.

**General Description.**—The Vomer is a delicate symmetrical rod, forming the lower part of the septum which divides the two nasal chambers. It is a direct continuation forward of the base of the cranium, inasmuch as it articulates behind with the anterior end of the sphenoid (Fig. 298). Its grooved upper surface receives the lower edge of the mesethmoid and the cartilaginous nasal septum. Its under surface is thickened in front and joins the upper surfaces of the horizontal plates of the maxillary and palatine bones. At the posterior part, the sides are laterally expanded, causing the bone to assume the shape of a prostrate cross. The upper part of the cross, which is the posterior part of the bone, is compressed from above downward, and the lower



FIG. 297.

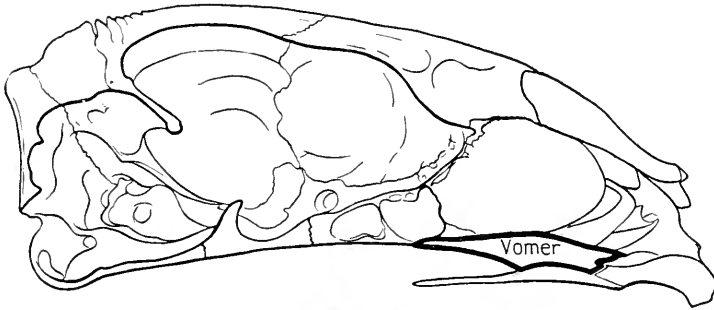


OUTER WALL OF LEFT NASAL CAVITY FROM WITHIN, ETHMOID REMOVED.

part is compressed from side to side. The side pieces are broad and thin, and their anterior borders are hooked.

The upper surface of the vomer (Fig. 297) is marked by a deep longitudinal median furrow for the ethmoid and its cartilage. This occupies all the surface at the anterior part of the bone, but behind, on

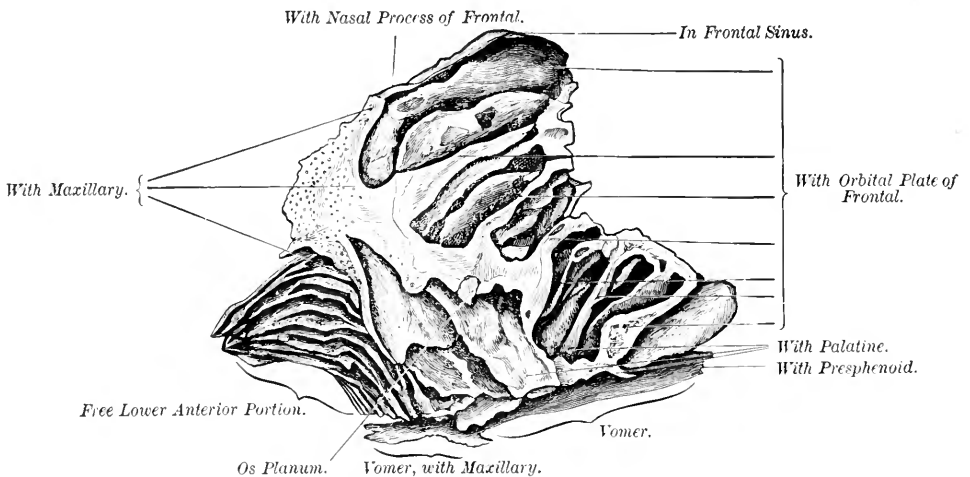
FIG. 298.



POSITION OF VOMER. MEDIAN SECTION.

each side, where the bone widens out and is separated from the furrow by a sharp ridge, is a well-marked slightly concave area, to which are fastened the lower ends of some of the ethmoidal convolutions. The

FIG. 299.

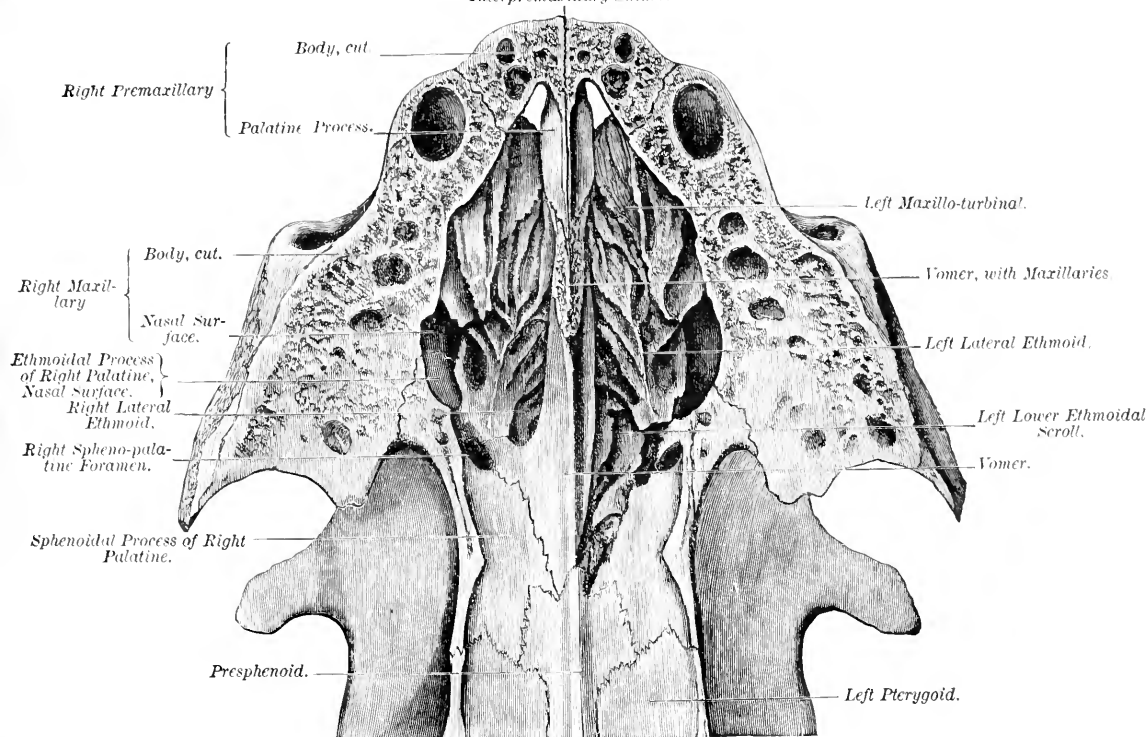


THE ETHMOID AND VOMER, LEFT SIDE, OUTER SURFACE.

anterior hook-like angles are fastened to the lower end of that plate of the lateral ethmoid which forms the posterior boundary of the ethmoidal cleft (Figs. 299, 300).

The posterior end of the vomer, the end of the cross, is deeply incised in the middle; the two lateral projections are applied to the anterior part of the inferior surface of the presphenoid.

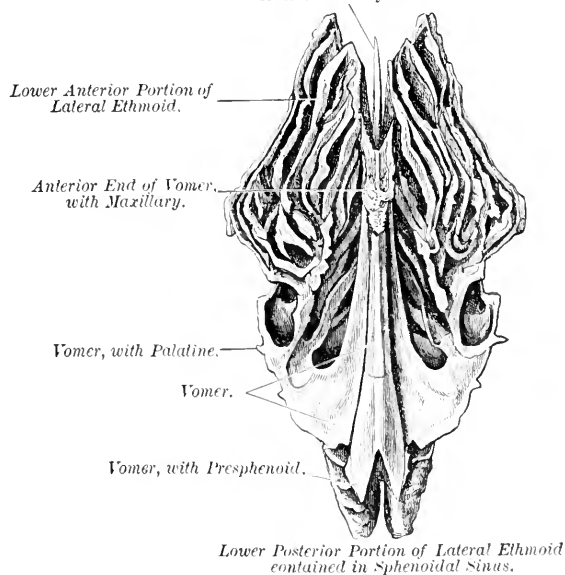
FIG. 300.

*Interpremaxillary Suture.*

## NASAL FOSSAE FROM BELOW.

Palatine Processes of Maxillaries and Palatines removed. Left side of posterior part of Vomer cut away.

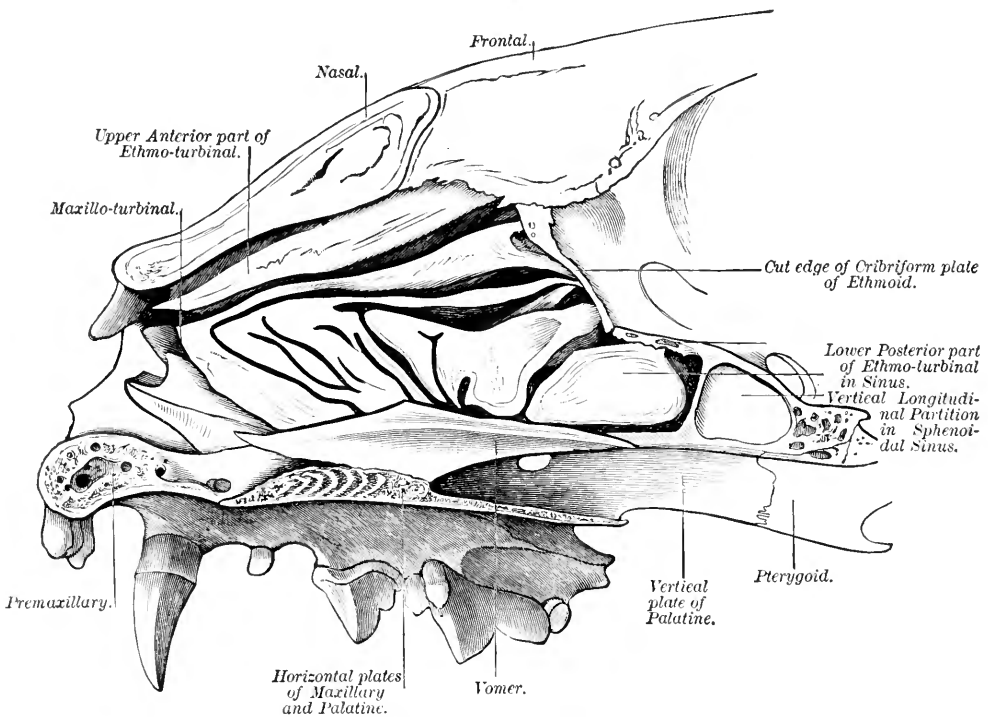
FIG. 301.

*Anterior End of Mesethmoid.*

## THE ETHMOID AND VOMER, LOWER ASPECT.

The lower surface of the vomer (Fig. 301) has the same general form as the upper surface; it presents, however, a median longitudinal ridge instead of a median longitudinal furrow. The anterior third, or more, of this ridge is roughened, and articulates with the anterior median part of the upper surface of the joined horizontal plates of the palatines and with the median borders of the horizontal plates of the maxillaries. The anterior end is incised to receive the posterior ends of the palatine plates of the two premaxillaries. The rest of the lower surface is smooth and non-articular; it is covered with mucous

FIG. 302.



RIGHT NASAL CHAMBER, SIDE VIEW FROM WITHIN.

membrane, and forms the roof of the canal which leads from the nose to the posterior nares. The vomer can scarcely be said to have lateral surfaces; they are mere borders which widen in front, as the sides of the prominent inferior ridge. Each edge of the expanded posterior portion joins (1) the lower edge of the lateral ethmoid, (2) a ridge just over the spheno-palatine foramen on the nasal surface of the ethmoidal process of the palatine, and (3) the sphenoidal process of the palatine (Fig. 300). The vomer slopes slightly downward at the anterior end, and this slope is apparently increased the greater the height of the bone.

**Nomenclature.**—Vomer is the Latin for ploughshare, which to a certain degree this bone resembles in shape. The vomer for a long time was not recognized as a distinct bone, having been classed as part of some one of the neighboring bones, until Fallopius and Columbus announced its independent character. Columbus gave it the present name. The term *os vomeris* is also employed, which the Germans translate into *das Pflugscharbein*. The French name is *le vomer*.

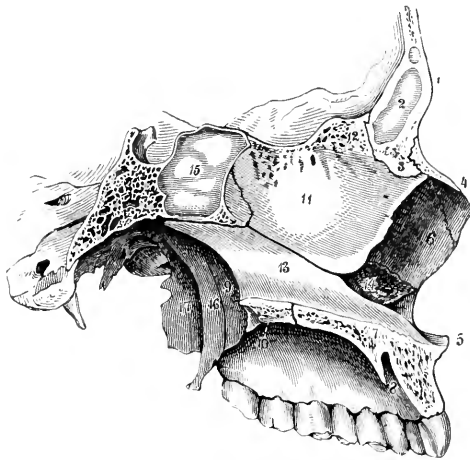
**Articulation.**—The vomer articulates with the premaxillaries, the maxillaries, the palatines, the presphenoid, and the ethmoid.

**Ossification.**—The vomer is developed from two centres of ossification.

### HUMAN VOMER.

The vertical height of the nasal chambers of man is so much greater than the height of the nasal chambers of the cat, that the vomer, which in each case forms the lower part of the dividing nasal septum, is higher in the human skull than in the skull of the cat. It is also narrower, even in its more expanded posterior part. That

FIG. 303.



VERTICAL SECTION OF THE FACE, EXHIBITING THE OSSEOUS NASAL SEPTUM.

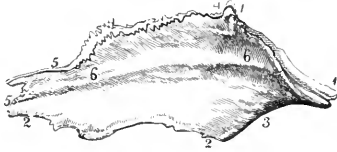
1, frontal bone; 2, frontal sinus; 3, nasal spine of the frontal bone; 4, nasal bone; 5, nasal spine of the maxillary; 6, nasal process of the same bone; 7, border of the palatine plate of the same; 8, incisive foramen; 9, left posterior naris; 10, palatine plate of the palatine bone; 11, nasal plate of the ethmoid bone; 12, ethmoidal crest; 13, vomer; 14, left maxillo-turbinal bone; 15, sphenoidal sinus; 16, internal pterygoid plate; 17, external pterygoid plate.

portion of the lower border which is not attached to the maxillary-palatine crest slopes obliquely upward and backward and becomes a true rounded posterior border, separating the posterior nasal openings (Fig. 303).

The vomer presents three other borders, limiting its two surfaces.

The short upper border (Fig. 304) is expanded on each side into a wing or ala, which is applied to the side of the sphenoidal rostrum and the edge of which joins the edge of the vaginal process of the pterygoid behind and the edge of the sphenoidal process of the palatine in front. Between the wings of the vomer and the sphenoids are three canals, one median, and two lateral, for blood-vessels and nerves.

FIG. 304.



THE VOMER, LEFT SIDE.

1, broad groove receiving the rostrum of the sphenoid bone; 2, inferior border articulating with the palatine plates of the maxillaries and the palatine bones; 3, posterior border, the dividing line of the posterior nasal orifices; 4, grooved border receiving a narrow slip of cartilage, situated between the vomer and the mesethmoid; 5, border for the cartilaginous septum of the nose; 6, nasal surface.

The anterior border joins the mesethmoid and the cartilaginous nasal septum (Fig. 303).

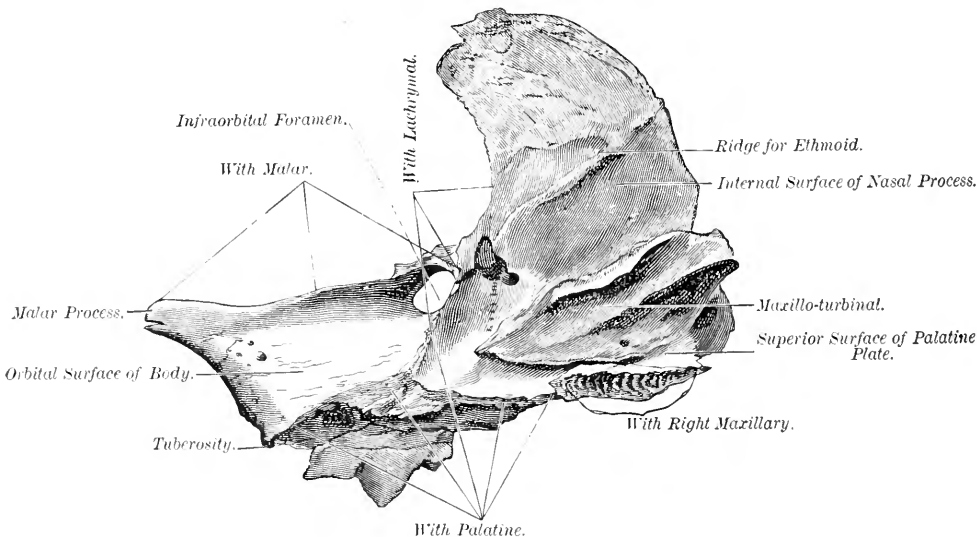
The inferior border unites with the maxillaries and palatines.

On each lateral surface is a distinct oblique groove for the nasopalatine nerve.

### THE MAXILLO-TURBINAL BONES.

**General Description.**—The Maxillo-turbinals are oblong masses, situated in the lower outer part of each nasal chamber (Figs. 305, 306). Each bone is composed of a few scrolls, attached by a thin plate to the outer wall of the chamber on an oblique raised line, which

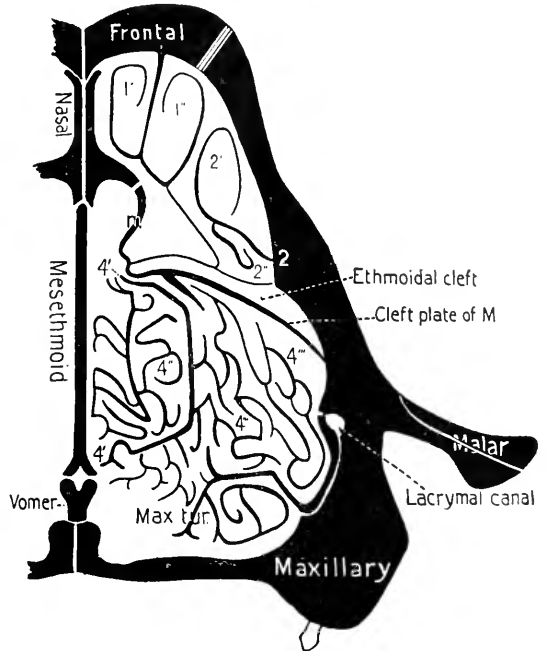
FIG. 305.



LEFT MAXILLARY BONE. SUPERIOR SURFACES.

begins in front at the lower part of the ascending plate of the maxillary and passes downward and backward on the outer part of the upper surface of the palatine plate of that bone.

FIG. 306.



TRANSVERSE SECTION OF HALF OF FACE.  
Showing position of maxillo-turbinal bone.

ward, and from in front backward and downward. The outer edge is emarginate near the middle, to form the lower opening of the lachrymal canal. The superior scroll is a curved plate which fits between the lower part of the ethmoidal scroll number 4''' on the outside and number 4' on the inside. The inferior scroll forms the rest of the bone and splits up into several secondary small divisions. The maxillo-turbinal is covered with mucous membrane, and is attached by fibrous tissue to the prenasal cartilages, which guard the entrance to the anterior nares. A space left between this bone, the median inter-nasal septum, the outer wall and the floor of the nasal cavity, is part of the inferior meatus of the nasal chamber. The space between the lower part of the lateral ethmoid and the maxillo-turbinal is the middle nasal meatus.

**Nomenclature.**—The maxillo-turbinal is sometimes called the inferior turbinated bone, *os turbinatum*, or *os turbinale*. The word is derived from *turbo*, a whirl; hence anything rolled into a scroll. *Concha nasalis inferior*, or *concha inferior*, from *concha*, a shell, has

been also employed, and is found translated into the German *das Muschelbein*, or *untere Muschel*. The French use *le cornet inférieur*.

**Determination.**—When the bone is held with the scroll-bearing medial side toward the student and the larger scroll downward, the pointed posterior end will be on the side to which the bone belongs.

**Articulation.**—The maxillo-turbinal articulates directly only with the maxillary; in some specimens it touches the lachrymal and the lateral ethmoid.

**Ossification.**—The maxillo-turbinal is developed from a single centre of ossification.

### HUMAN MAXILLO-TURBINAL BONES.

The human maxillo-turbinal, often known as the *inferior turbinated bone*, is more simple than the corresponding bone of the cat, in that it consists of a single scroll.

It presents a convex *inner surface* (Fig. 307) and a concave *outer surface* (Fig. 308); both *extremities* are pointed, the posterior more acutely.

FIG. 307.



THE RIGHT NASAL CAVITY, OUTER WALL.

1, frontal bone; 2, its orbital plate; 3, its nasal spine; 4, nasal bone; 5, ethmoid bone; 6, superior turbinal; 7, middle turbinal; 8, maxillo-turbinal bone; 9, descending process of the lachrymal bone, within the position of which is the nasal duct; 10, nasal spine of the maxillary; 11, naso-palatine canal; 12, palatine plate of the maxillary; 13, nasal process of the latter; 14, external pterygoid plate; 15, internal pterygoid plate; 16, nasal plate of the palatine bone; 17, its palatine plate; 18, posterior palatine foramen; 19, superior meatus of the nose; 20, middle meatus; 21, inferior meatus; 22, frontal sinus; 23, sphenoidal sinus; 24, its communication with the upper back part of the nasal cavity; 25, sphenopalatine foramen; 26, orifice of the antrum.

The superior border gives off in front and above a lachrymal process, which articulates with a process of the lachrymal bone. Behind this process is an ethmoidal process, which projects upward



and joins the uncinate process of the ethmoid. The superior border is prolonged outward and downward as a broad maxillary process, which, with the border itself, is fastened to the inner surface of the nasal process of the maxillary bone, partially closing the opening of the antrum (Fig. 281).

FIG. 308.



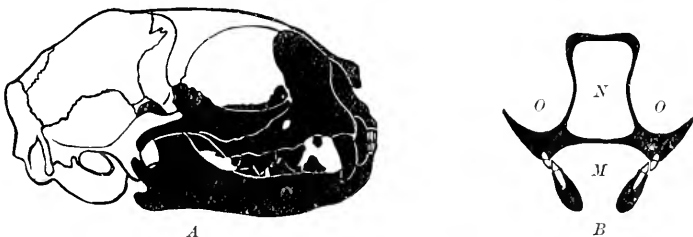
RIGHT TURBINAL BONE, EXTERNAL VIEW.

1, anterior extremity, articulating with the maxillary; 2, posterior extremity, articulating with the palatine bone; 3, hook-like maxillary process, articulating with the lower border of the maxillary antrum. Above are the lachrymal and ethmoidal processes; 4, inferior obtuse border.

### THE MANDIBLE.

**General Description.**—The Mandible, or Lower Jaw, is a V-shaped arch of bone which forms the inferior boundary of the mouth (Fig. 309). Its free extremities are articulated to the temporal bone of the skull. Its apex forms the chin. In its upper border are planted the lower teeth. Each half of the arch consists of a separate bone, meeting its fellow in front at an angle of about fifty degrees and in the natural state joined with it by an immovable articulation or symphysis (Fig. 310); upon maceration the two sides fall apart. They may be called the right and left inferior maxillary bones, or the right and left halves of the mandible. Each half is a bony bar compressed from side to side and consisting

FIG. 309.



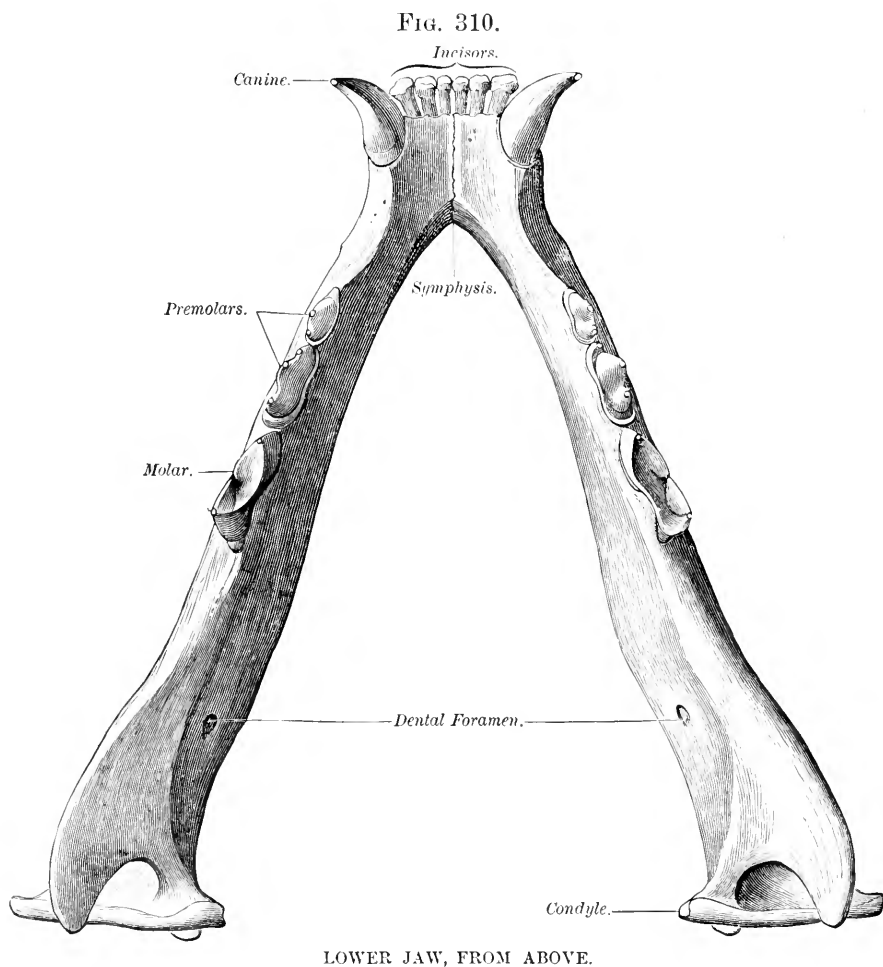
THE FACE.

A, side view of the skull, bones of the face black. B, diagrammatic transverse section, showing relations of the nasal cavity, N, the orbital cavities, O, and the mouth, M.

of two parts (Fig. 311),—an anterior, longer, more slender, horizontal ramus, or body; and a posterior, shorter, more elevated part, called the ascending ramus. The two parts are not sharply defined, the surfaces and borders of one passing without material change of form or direction into the corresponding surfaces and borders of the other, but all the bone in front of the last tooth is regarded as body, and all behind and above it as ascending ramus.

The **Body** presents external and internal surfaces, and superior, inferior, and anterior borders.

The **external surface** is bounded above by the superior border; in front by the anterior border; and below by the anterior and inferior borders. Behind, it passes into the external surface of the ascending ramus. It is about three times as long as wide. The upper and lower margins are nearly parallel, and are curved slightly upward. The

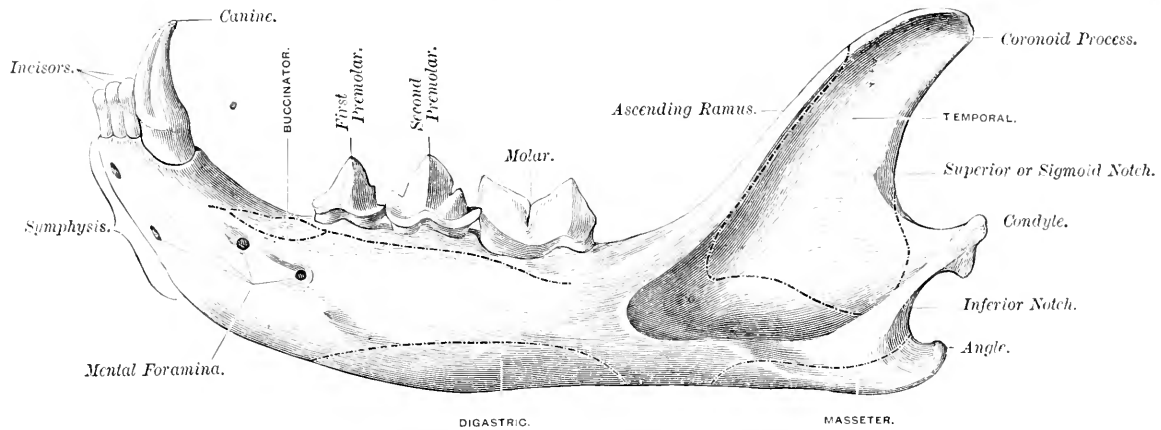


anterior end is cut off obliquely, the anterior border running backward at the expense of the lower border.

The external surface is gently convex in both directions, and its anterior part turns boldly inward round the root of the canine tooth, and, with the corresponding surface of the opposite bone, faces forward and downward when the two bones are united at the symphysis. The position of the root of the canine is marked by a prominent swelling,

behind which is a shallow, wide, vertical groove, which is continued on the superior border as an emargination. This groove receives the upper canine tooth. Close to the anterior margin are two or more small **mental**<sup>1</sup> foramina, the anterior orifices of the inferior dental canal. Behind the canine swelling, midway between the upper and the lower border, are two larger openings of the same canal. The anterior opening is situated in the shallow groove mentioned above, and the posterior three or four millimetres behind it. The anterior is

FIG. 311.



LOWER JAW, LEFT SIDE, OUTER SURFACE.

usually larger than the posterior, and may be double; the posterior may be very small or entirely absent. There is frequently a second smaller posterior foramen below, either behind or in front of the main foramen, and there are several smaller inconstant openings on and around the canine swelling. The buccinator muscle is attached to the external surface along a line a little below the upper border, and the digastric muscle is attached to the posterior lower part.

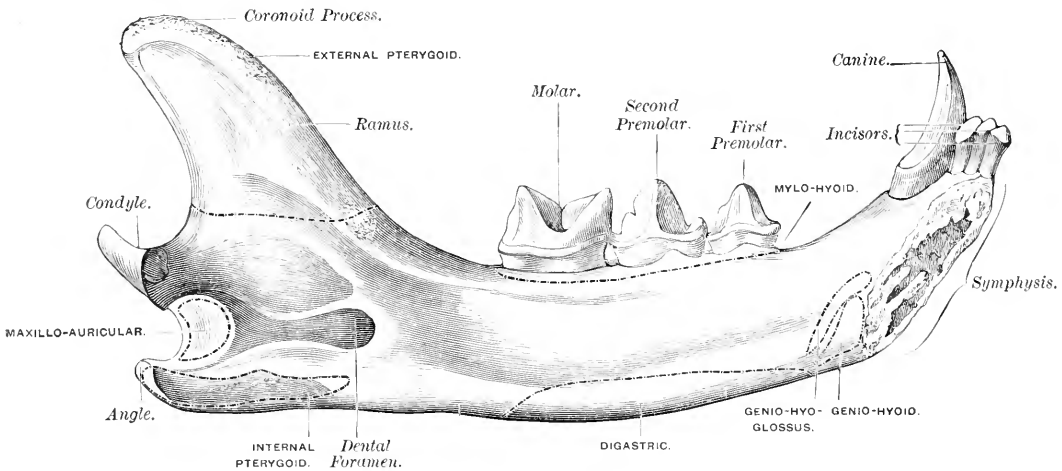
The **internal surface** of the body of the mandible (Fig. 312) presents little worthy of note. It has the shape of the external surface; the upper and lower borders are nearly parallel, and the anterior end is produced into an upward and forward prolongation to receive the canine and incisor teeth. It is almost flat, slightly convex from above downward, and curved from behind forward and inward. Near the posterior end of its upper border is the beginning of the obscure **internal oblique line** which runs downward and forward and marks the attachment of the mylo-hyoid muscle.

<sup>1</sup> From *mentum*, the chin.

At the anterior end of the surface is the roughened area for articulation with the other half of the jaw. This area is pear-shaped, the apex pointing downward and backward. Its anterior straight, slightly serrated border is the anterior border of the bone. The upper half of its posterior upper border is sharp and elevated, forming with the border of the other half a prominent median ridge, below which are attached the hyo-glossus and genio-hyo-glossus muscles. Between this ridge and the superior border of the bone is a shallow, vertical groove.

The superior border of the body of the mandible is known as the alveolar border, because it contains the alveoli, or cavities for the roots of the teeth. It consists of a long posterior portion for the molars and premolars, and a short, elevated anterior portion for the canines and

FIG. 312.



LOWER JAW, LEFT SIDE, INNER SURFACE.

incisors. The two parts are separated by a transversely depressed interval called the **diastema**. The posterior part is of moderate width; it is arcuate externally and faces outward as well as upward. It contains six deep pits, or alveoli, arranged in three groups of two each, to receive the roots of the three posterior lower teeth. Each group of two alveoli is placed slightly obliquely to the axis of the bone, so that the anterior alveolus is nearer to the median line of the skull than the posterior. The alveoli increase in size from before backward, except the last alveolus, which is as small as the first. The posterior roots of the first two teeth therefore are stouter than the anterior roots, but the anterior root of the last tooth is stouter than the posterior. The alveoli are directed downward and inward, and the larger ones extend more

than half-way through the bone. The anterior part of the alveolar border turns inward and becomes nearly transverse to the axis of the bone; it is connected with the posterior part by a sharp curved ridge lying on the inner side of the bone. It is almost entirely occupied by the large opening of the alveolus for the canine teeth, between which and the symphysis the border is narrow and contains, in a perfect jaw, three transversely placed small alveoli for the incisors. The canine opening is oval; the long diameter is directed from before backward; its edge is sharp, and its cavity is curved backward and downward. The alveoli are subject to variation. Those for the incisors are rarely entirely separated from one another or placed in a transverse line. Age and disease lead to the loss of the teeth and the subsequent absorption of the alveoli.

The **lower border** of the body is known as its base. It is heavy and rounded except just in front near the symphysis, where it is sharp and lies on the median side of the bone. Near its middle, where the digastric muscle is attached, it frequently bends slightly upward.

The **Ascending Ramus** has the shape of a right-angled triangle, whereof the lower anterior angle is truncated and applied to the posterior end of the body. Its upper part is the **coronoid**<sup>1</sup> process. The **condyle** for articulation with the temporal bone of the cranium is placed transversely across its posterior border. The ascending ramus presents three borders and two surfaces:

The **anterior-superior border** begins above at the tip of the coronoid process. It passes, as a thin edge, at first upward and forward, then arches downward and forward, becomes gradually broader, and ends below in the upper border and external surface of the body. It faces at first upward and backward, then upward and inward, and finally upward and outward. It is more sharply defined from the external than from the internal surface.

The **inferior border** is continuous with the inferior border of the body, which it resembles. The posterior part is narrow and turns inward to end in the **angle** of the jaw. The border affords attachment to the masseter muscle.

The **posterior border** is divided into two parts by the condyle.

<sup>1</sup> From (Gr.) *corone*, a hook like a crow's bill, and *eides*, like. *Corone* was also applied to the hook on the tip of the bow to which the bow-string was attached; in this sense it was first introduced into anatomy by Galen.

(1) The upper part is also the posterior border of the coronoid process. It is twice as long as the lower part, narrow and rounded and deeply emarginate, forming between the tip of the coronoid process and the condyle the **superior, or sigmoid,<sup>1</sup> notch**. It becomes transversely wider below and terminates near the inner end of the condyle. (2) The lower part presents a sharp border beginning above at the outer end of the condyle and running obliquely downward and inward to meet, at the angle, the upturned posterior end of the lower border. From this border the triangular space included between the angle and the base of the condyle slopes forward and inward to become continuous with the internal surface. This space receives the insertion of the maxillo-auricular muscle.

The **angle** is a blunt hook pointing inward and backward; in the natural state it is embedded in the masseter muscle.

The **condyle** is a bony cylinder, four or five times as long as wide, placed across the posterior border of the ascending ramus. The long axis is not transverse to the long axis of the lower jaw, but forms with it a decided angle; the outer end is directed backward and the inner end forward. When the two sides of the jaw are in place, however, the two condyles lie in a line transverse to the long axis of the skull. The condyle is narrow and pointed at the outer end. Its upper articular surface is emarginate in front, and separated behind from the non-articular part by a straight line. The condyle is sometimes described as the posterior part of the **condyloid process**, which is narrow above, wide below, and not well defined on the outside; it is separated from the ramus by a **neck**.

The **external surface** of the ascending ramus (Fig. 311) is almost entirely occupied by a large deep **fossa** which is limited by an elevated sharp superior border, a rounded lower border, and a well-defined line from the outer tip of the condyle to the lower border. The fossa ends in front in a shallow point near the posterior part of the outer surface of the body of the bone. The temporal muscle is attached in the fossa and to its edge; the masseter is attached to the lower border.

The **internal surface** (Fig. 312) has the shape of the external; it is flat, and slightly roughened for muscular attachment. The **dental foramen** pierces the middle of the lower third obliquely forward and outward and leads into the **inferior dental canal**, which lodges the

<sup>1</sup> From (Gr.) *sigma*, the letter Σ or S, in its older form C, and *eides*, like.

vessels and nerves supplying the lower jaw and the teeth. This canal occupies nearly all the interior of the body of the bone. In it, from above, depend the hollow pegs which form the tooth-sockets; they are connected with the lateral walls by bands of cancellous tissue. Inasmuch as these sockets are shorter in front, the canal appears to be highest at the anterior premolar region. Each socket is perforated to allow entrance and exit to the nerves and vessels of the tooth. Behind the molar tooth the canal communicates with the cancellous tissue; it ends in front at the side of the canine. The anterior margin of the dental foramen is sharp, and on the upper margin is frequently found a **spine** indicating the attachment of the spheno-maxillary ligament. The external surface forms, behind, an internal root for the condyloid process, below which it passes outward and backward into the subcondyloid space.

**Nomenclature.**—Mandible is from *mandibula*, introduced by Macrobius in the fifth century for both upper and lower jaws. It is derived from *mandere*, to chew. Pliny (A.D. 23–79) employed *maxilla inferior*, whence the name the inferior maxillary bone. The Germans have *das Unterkieferbein* and *der Kinnlade*. The French have *le maxillaire inférieur*.

**Articulation.**—The mandible articulates with the temporal bone of the cranium.

**Muscular Attachments.**—To the outer surface of the lower jaw are attached the temporal, the masseter, and the buccinator; to the inner surface, the external pterygoid, the internal pterygoid, the maxillo-auricular, the mylo-hyoid, the genio-hyoid, and the genio-hyo-glossus; to both surfaces and the lower border, the digastric.

**Ossification.**—Each half of the mandible develops from several centres of ossification, which early unite.

#### VARIATIONS IN THE MANDIBLE.

##### VARIATIONS IN SIZE.

One-half of the mandible is measured as follows:

The maximum length is the distance from the tip of the symphysis to the posterior point of the condyle.

The height of the ascending ramus is the vertical distance from the top of the coronoid to the lower border of the bone.

The length of the condyle is from the inner to the outer end.

The height at the anterior angle is taken on a vertical line transverse to the horizontal ramus, from the lower angle to a point behind the canine alveolus.

The maximum width of the body is the distance between the outer and inner surfaces taken at about the middle of the bone.

The length of the coronoid process is the distance from the upper side of the base of the condyle to the angle which the anterior border of the coronoid process makes with the alveolar border.

Maximum Length.	Height of Ramus.	Length of Condyle.	Height at Anterior Angle.	Maximum Width.	Length of Coronoid Process.
50.5	23	12.5	7.5	5	17
52	24	11	8.5	5	18
52	24	12	9	5	19
52.5	21.5	10.5	8	4.5	19
53	21	11	8.5	5	18
53	22	12	8.5	5	19
54	24.5	13	9	5	18
54.5	24	12.5	9	5	19
55	23	12	9	5	19
55	25	12	8	5	20
55	26	13	9	6	23
55.5	23	11.5	8.5	5	19
55.5	24	12	9	5	20
55.5	25	12	8	5.5	20.5
56	24	12	9	5	20
56	24.5	13	9	6	20
56	24.5	12	9	5.5	20
56	25	13.5	9	5.5	20
56	26	12	9	5.5	21
56	26	13	9	5.5	20
56.5	25	12.5	9	5	21
56.5	25	13	8	5	21
56.5	26	13	9	5.5	19
56.5	27.5	13	8	5	22
57	24	13	10	6	20.5
57	25	13.5	8	5	20
57	25	13	9	5.5	20
57.5	25	12	10	5.5	21.5
58.5	25	12.5	10	5.5	19.5
59	24.5	14	9	5	22
59	25.5	12.5	18.5	5.5	22
59	27	14	10.5	8	22
59.5	24.5	13.5	9	5	22
60.5	28	14	10	6	22
60.5	29	14	10	6	21
64	26	14	10	5.5	24
64	27	15	10	6	23
64	27	13	11	7	23
64	29	13	10	6	25
67	30	15	10	7	24
68.5	30	16	11	6	25



The measurements of the entire mandible may be made as follows :

The width is taken (1) between the inner ends of the condyles ; (2) between the tips of the coronoid processes ; (3) between the inner edges of the angles ; (4) between the tips of the canine teeth ; (5) between the posterior cusps of the molars ; and (6) between the outer edges of the canine alveoli.

The superior length of the mandible is the distance from the median point of the anterior edge of the alveolar border to the middle of an imaginary transverse line through the posterior edges of the condyles.

The inferior length is the distance from the posterior lower end of the symphysis to the same point on the posterior transverse line.

WIDTH.					LENGTH.		
Condylloid.	Coronoid.	Angular.	Canine.	Molar.	Alveolar.	Inferior.	Superior.
40	54	47	17	35	14	46	53
33	50	45	15	32	14	51	60
32	48	42	17	31	14	48	58
31.5	47	39	16	28	13	45	65
31	47	40	14	29.5	12	43	51
31	46	39	16	30	13	46	54
31	45	40	14	30	12	44	52
30.5	48	42	17	31.5	15	50	61
30	48	39	17	29	13.5	46	55
30	47.5	39	14	30	11	40	50
30	47	38	15	30	13	44	53.5
30	47	37	14.5	29	13	45	55
30	47	37	18	30	13.5	50	60
30	46	41	15	30	12	46	53
30	43	40	15	30	13	45	54.5
30	45	44	16	32	12	45	56
29.5	44.5	35	15	27	12	41	51
29	47	39	18	29	13	46	50
29	45	37	16	29	13.5	44	53.5
29	44	38	15	28	12	44	52
28	44	40	12	29	11	41	50
28	44	35	14	28	12	42	50
28	43	35	14	27	12	40	50
28	42	39	13	26	11	41	49
26	45	37	9	27	12	40	49

#### VARIATIONS IN FORM AND DEVELOPMENT.

In the alveolar border, the sockets for the incisors are frequently irregular ; that for the middle incisor is usually behind the other two. The other alveoli are very constant ; in one specimen examined the

molar tooth had a minute additional fang, which was planted in a little alveolus on the outer side of the posterior fang.

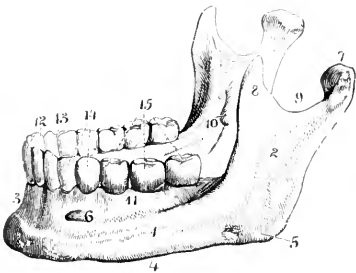
The variations in the anterior dental foramen have been already pointed out (page 389). When the lower border of the bone is held horizontally, the posterior border of the coronoid process may be vertical, or it may incline backward, so that the tip, which in some specimens is slightly hooked, extends beyond the condyle.

The condyle varies in relative length and width; the outer end is often pointed. The upper surface of the angle frequently presents a deep fossa which is distinct from the fossa under the condyle.

### HUMAN MANDIBLE.

In man the adult lower jaw is a single bone; the two halves early coalesce at the median symphysis. As a single bone it may be described as consisting of a horseshoe-shaped body, from each posterior end of which rises an almost vertical ramus (Fig. 313).

FIG. 313.



MANDIBLE.

1, body; 2, ramus; 3, symphysis; 4, base; 5, angle; 6, mental foramen; 7, condyle; 8, coronoid process; 9, mandibular, or sigmoid, notch; 10, dental foramen; 11, alveolar process; 12, incisor teeth; 13, canine tooth; 14, premolars; 15, molars.

The body is vertical at the median symphysis; instead of sloping downward and backward, as in the cat, it is produced forward to form a chin, or **mental protuberance**. Above the chin on the **external surface** is the incisive fossa for the levator mentis muscle, and behind this, on each side and on a level with the second premolar tooth, is the **mental foramen**.

The **external oblique line** extends from the mental protuberance to the anterior border of the ramus; it offers attachment for the depressores labii inferior and anguli oris muscles. The buccinator muscle is attached to the external surface near the superior border, and the platysma myoides at the rounded inferior border.

The **internal surface** of the body exhibits in front, at the lower part of the symphysis, two pairs of **tubercles**, whereof the upper pair is for the attachment of the genio-hyo-glossus muscle and the lower pair for the attachment of the genio-hyoid muscle. The shallow space on each side of these tubercles is called the **sublingual fossa**; the roughened depression below them is for the insertion of the digastric

muscle. The **internal oblique line**, which begins in front near the tubercles, becomes more prominent as it nears the alveolar border, behind; to it is attached the mylo-hyoid muscle, and in the groove below is lodged the submaxillary gland.

The **superior border** contains the alveoli of sixteen teeth, eight on each side, which are, two incisors, one canine, two premolars, and three molars.

Each **ramus**, or **ascending ramus**, is more vertical than the corresponding part of the mandible of the cat. The condyloid process is high up at the posterior superior angle; the coronoid process is relatively low, and the sigmoid notch on the superior border is almost horizontal. The angle is less prominent and rounded, and there is no true inferior notch in the posterior border.

The **condyle** is relatively narrower than the mandibular condyle of the cat; its long axis is transverse to the long axis of the ramus, but not transverse to the long axis of the skull; the outer end, bearing the **condyloid tubercle**, is more anterior than the inner end. It has a decided **neck**, which is flattened in front for the attachment of the external pterygoid muscle.

The lesser width and increased rotundity of the condyle and the manner of its articulation in the glenoid cavity of the temporal give to the lower jaw a larger range of motion than is given by the wider and sharper condyle in the cat; hence the posterior teeth are true grinding teeth and are not modified into shearing instruments.

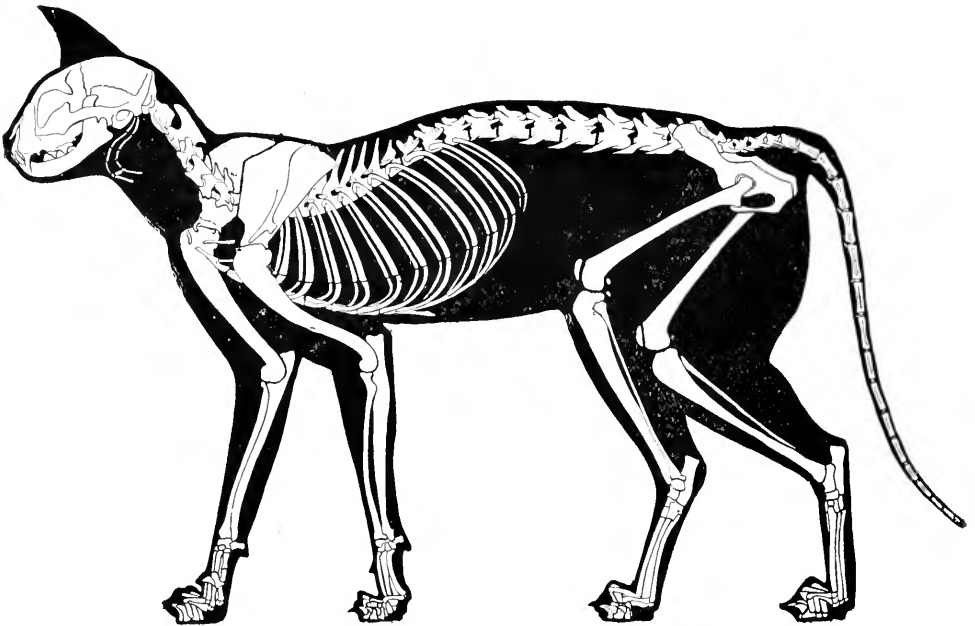
The **external surface** of the ramus is not deeply depressed by a temporo-masseteric fossa; it is rough and receives the masseter muscle only; the temporal muscle, which in man is small compared with the temporal of the cat, is inserted upon the end of the coronoid process. The **internal surface** is marked by the large **dental foramen**, guarded in front and above by the **mandibular spine**. The groove passing downward and forward from the foramen is for the mylo-hyoid nerve and artery. Behind the groove is inserted the internal pterygoid muscle.

#### THE HYOID BONES.

**General Description.**—The Hyoid apparatus consists of two slender, jointed rods, each of which is attached by its upper end to the skull (Fig. 314) within the mastoid process of the temporal bone, and at its lower end is joined to its fellow by a shorter unjointed transverse

rod, to form a bony swing which supports the root of the tongue. At each end of the transverse bar, a rod extends backward at right angles and joins the larynx, the expanded upper end of the trachea, or windpipe. The hyoid bones can be felt in life at the upper part of the neck, in the anterior angle formed by the neck and the under part of the jaw. They are attached by muscles to the skull, the lower jaw, the larynx, and the sternum.

FIG. 314.



THE SKELETON OF THE CAT.

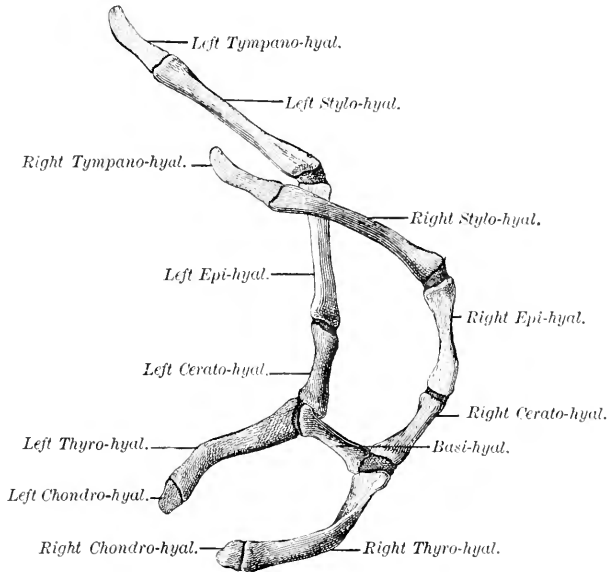
The larger jointed rod (Fig. 315) is arched forward and slants inward and upward. It is composed of four elements: an upper elongated piece of cartilage known as the tympano-hyal, which forms the union to the skull; a second longer slender bar, the stylo-hyal; a shorter third piece, the epi-hyal; and a small quadrate terminal ossicle, the cerato-hyal. The transverse bar is called the basi-hyal, or body of the hyoid. The posterior elements which support the thyroid cartilage of the larynx are known as the thyro-hyals. The different elements of the hyoid apparatus are joined together by intervening pieces of cartilage which vary in size according to the age of the specimen.

The **tympano-hyal** (Figs. 315, 316) is an elongated, flattened piece of cartilage, the upper end of which is received into a pit in the

auditory bulla of the skull. To it are attached the stylo-glossus and stylo-pharyngeus muscles.

The **stylo-hyal** is the longest and, withal, the most slender of the elements. It is subcylindrical, slightly enlarged at the ends, and flattened on the shaft from without inward. It is faintly bowed forward, and its upper end is turned gently outward. It furnishes attachment to the stylo-glossus muscles.

FIG. 315.



HYOID BONES, VIEWED FROM BEHIND, ABOVE, AND THE RIGHT SIDE.

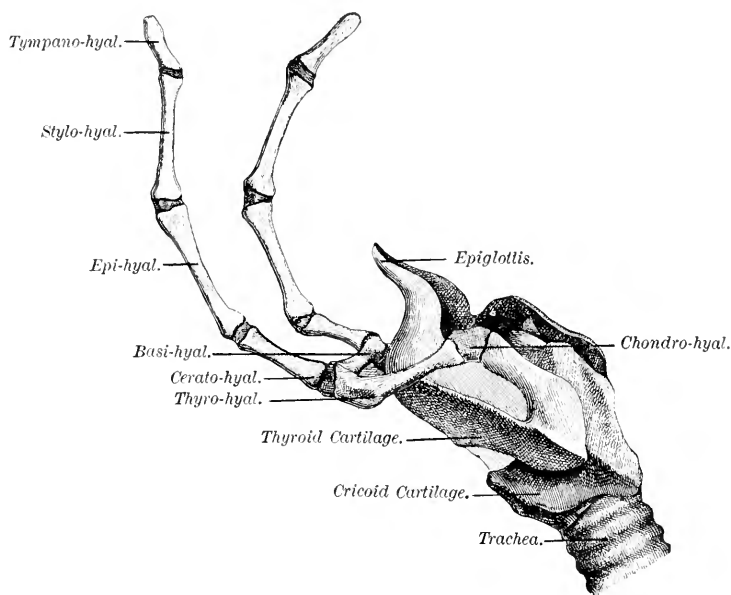
The **epi-hyal** is only half as long as the stylo-hyal, but is fully as wide; it appears, therefore, to be thicker. The upper end is hardly appreciably larger than the lower end. The shaft is flattened transversely and gently bowed outward. It furnishes attachment to the muscular constrictor of the pharynx.

The **cerato-hyal** is less than half as long as the epi-hyal; the upper end is smaller than the lower end, which is joined to a plate of cartilage which forms the union between the basi-hyal and the thyro-hyal. To the cerato-hyal is attached the hyo-glossus muscle.

The **thyro-hyal** is the thickest of all the hyoid bones. It is about as long as the epi-hyal, but can be distinguished from it by its emarginate upper and arcuate lower borders and its antero-posteriorly convex outer and concave inner surfaces. The bone may be therefore said to be bowed downward and outward. Its posterior end is prolonged by

the addition of a piece of cartilage, which turns downward to join the posterior upper part of the thyroid cartilage of the larynx (Fig. 316). This piece has been called the **chondro-hyal**. The thyro-hyal is united in front by cartilage to the basi-hyal and cerato-hyal and by a strong membrane from its lower border to the thyroid cartilage. It furnishes attachment to the thyro-hyoid muscle.

FIG. 316.



HYOID BONES AND LARYNX. LEFT SIDE.

The **basi-hyal** is not so long as the epi-hyal. It is straight, and presents upper and lower surfaces which furnish attachment to the genio-hyoid and sterno-hyoid muscles. Its ends are slightly enlarged and are joined by intermediate cartilages to the thyro-hyals. The basi-hyal also is united to the thyroid cartilage by membrane.

The hyoid apparatus is capable of not a little motion; it is elevated when the tongue is protruded, and alternately elevated and depressed in swallowing.

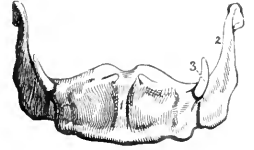
#### VARIATIONS IN THE HYOID.

An increase in the number of bony elements in the jointed anterior bar appears to be not uncommon; I have seen it in three specimens out of twenty-five examined. In each case the increase was on the right side only and was due to the interposition of a new element between the cerato-hyal and the epi-hyal, and at their expense. The additional bone was about half as long as a normal cerato-hyal.

## HUMAN HYOID.

The hyoid apparatus is so far reduced in man (Fig. 317) that it comprises a single median transverse bone, the body, or basi-hyal, and four smaller processes, two on each side,—namely, the small cornua, or cerato-hyals, and the great cornua, or thyro-hyals; the five pieces are suspended from the skull by two lateral ligaments, are joined to the cartilages of the larynx, and receive the insertions of many muscles.

FIG. 317.



THE HYOID BONE.

1, body; 2, great cornu; 3, small cornu.

The **body** presents a convex anterior surface, which is divided by a ridge into superior and inferior parts. The ridge sometimes exhibits a strong median tubercle. The posterior surface is deeply concave.

The **great cornua** project upward and backward; each cornu terminates in a rounded tubercle.

The **small cornua** are attached in the sutures between the body and the greater cornua. From their tips the stylo-hyoid ligaments proceed upward to the styloid processes of the temporal bones; these processes contain the tympano-hyal and stylo-hyal elements.

## CHAPTER VI

## THE TEETH

The Teeth are usually described as parts of the digestive system; they are developed from papillæ in the epithelium of the mouth, and their relation to the skeleton of the face is a secondary one. They are, however, so firmly planted in the jaw bones that they can be properly examined only after the skull has been cleaned and macerated; hence it is more convenient to study them in connection with the skeleton.

At birth the teeth are still concealed in their sockets or alveoli. If the gums be cut away, the edges of the jaws will exhibit an interrupted furrow roofed by cartilage. When the kitten is two or three weeks old the teeth begin to erupt through the gums, and usually before it is forty days old the entire first set is in place.

These first teeth are termed **milk teeth**; they are developed during the sucking period; inasmuch as they fall out and are replaced by a second set, they are more generally known as **deciduous teeth**. They number twenty-six in all,—on each side of the mouth thirteen, whereof seven are on the upper jaw and six in the lower jaw. They are divided into three groups: In front, above and below on each side and placed transversely, are the three small **deciduous incisors**.<sup>1</sup> Posterior and lateral to these is the long, conical deciduous **canine**, so named because of its prominence in the dog. It is sometimes termed the **laniary** <sup>2</sup> tooth. On each side, behind the canine in the upper jaw are three teeth, and in the lower jaw two teeth; these ten teeth are the **deciduous molars**.<sup>3</sup> It will be noticed that they differ in size and in form, the first in the upper jaw being very small and separated from the canine in front and the second deciduous molar behind by **diastemata**.<sup>4</sup>

When the cat has reached the age of about four months, the de-

<sup>1</sup> *Incidere*, to cut into.

<sup>2</sup> *Laniare*, to rend.

<sup>3</sup> *Mola*, a mill.

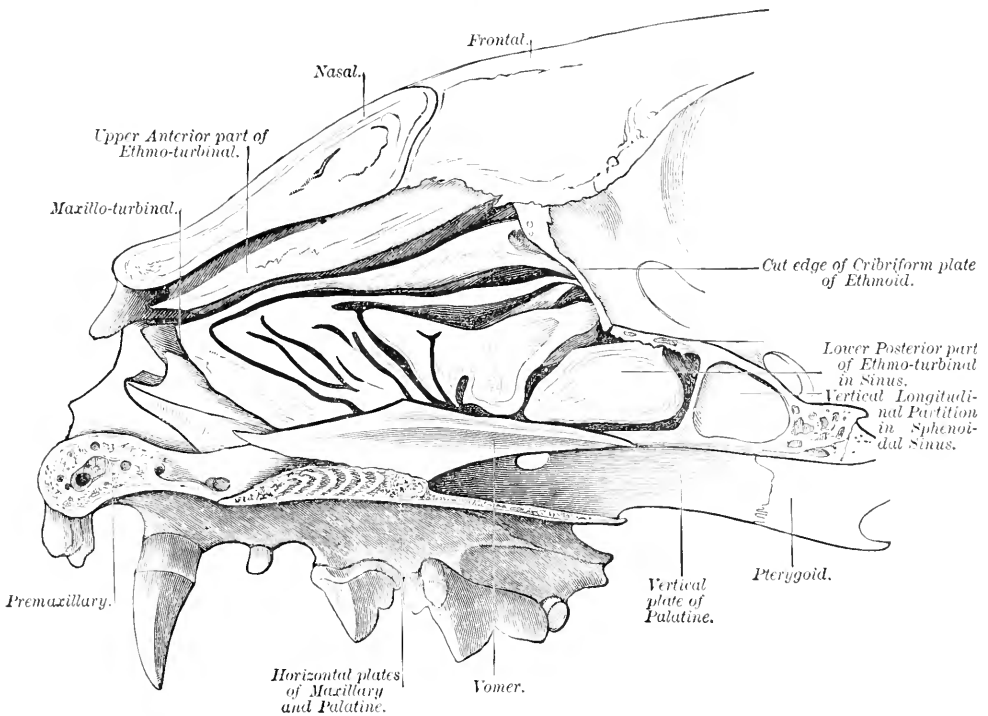
<sup>4</sup> Plural of *diastema*, an interval.



ciduous teeth begin to be pushed out by the eruption of the second or permanent set.

The permanent teeth number thirty in all. On each side, above and below (Figs. 318, 319), the three permanent incisors and the single permanent canine replace the deciduous incisors and the deciduous canine. On each side above, three permanent teeth replace the deciduous molars. Inasmuch as they are situated in front of the fourth permanent molar, which has no predecessor in the milk set, they are

FIG. 318.



RIGHT UPPER TEETH IN POSITION, MEDIAL VIEW.

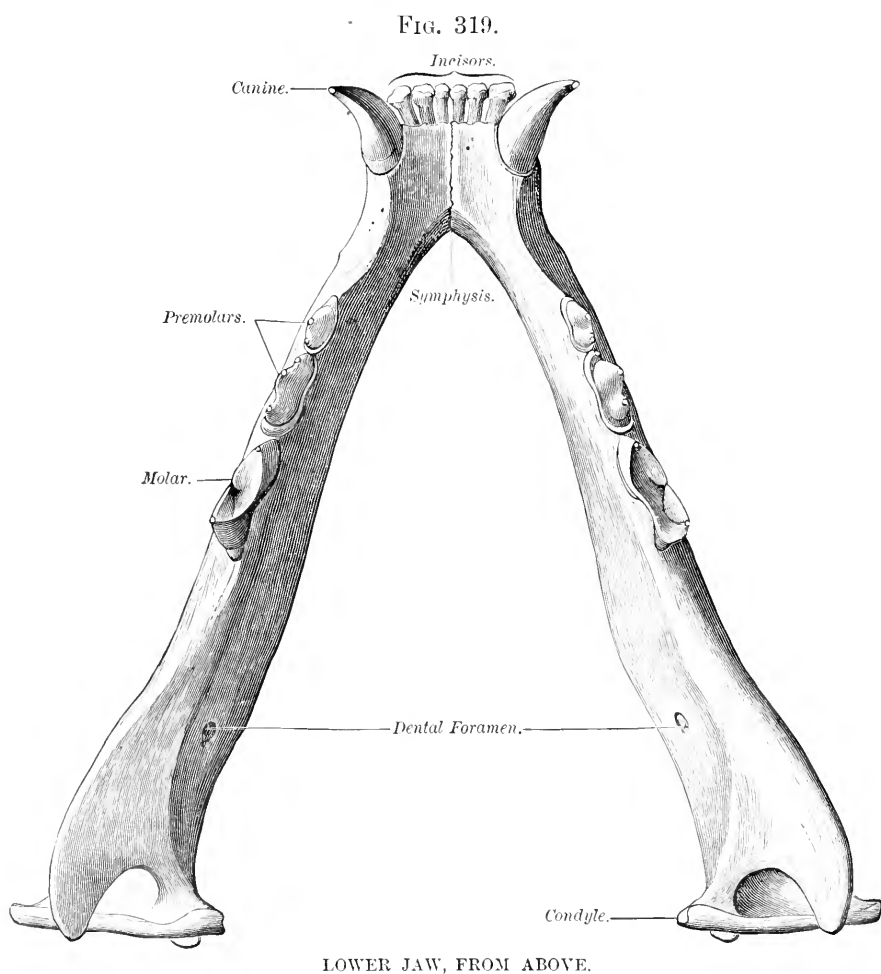
called **premolars**. The student should remember that all the milk teeth behind the canines are known as deciduous molars, but that in the permanent set the molars are such only as have no deciduous predecessors. In the lower jaw on each side, two permanent premolars replace the two deciduous molars, and a new permanent molar appears behind them.

We express the double dentition of the cat by the following formulæ, in which *d* stands for deciduous, *i* for incisor, *pm* for premolar, and *m* for molar; the numerator of the fraction represents the

number of upper teeth, the denominator the number of lower teeth, of any one kind: Milk teeth =  $di \frac{3}{3}$ ,  $dc \frac{1}{1}$ ,  $dm \frac{3}{2}$ .

$$\text{Permanent teeth} = i \frac{3}{3}, c \frac{1}{1}, pm \frac{3}{2}, m \frac{1}{1}.$$

The teeth are numbered from the middle point of the jaw in front backward; for example, the internal lower incisor is the first incisor, expressed by  $\frac{1}{i1}$ ; the middle incisor is the second,  $\frac{2}{i2}$ ; the lateral incisor is the third,  $\frac{3}{i3}$ ; and so on.

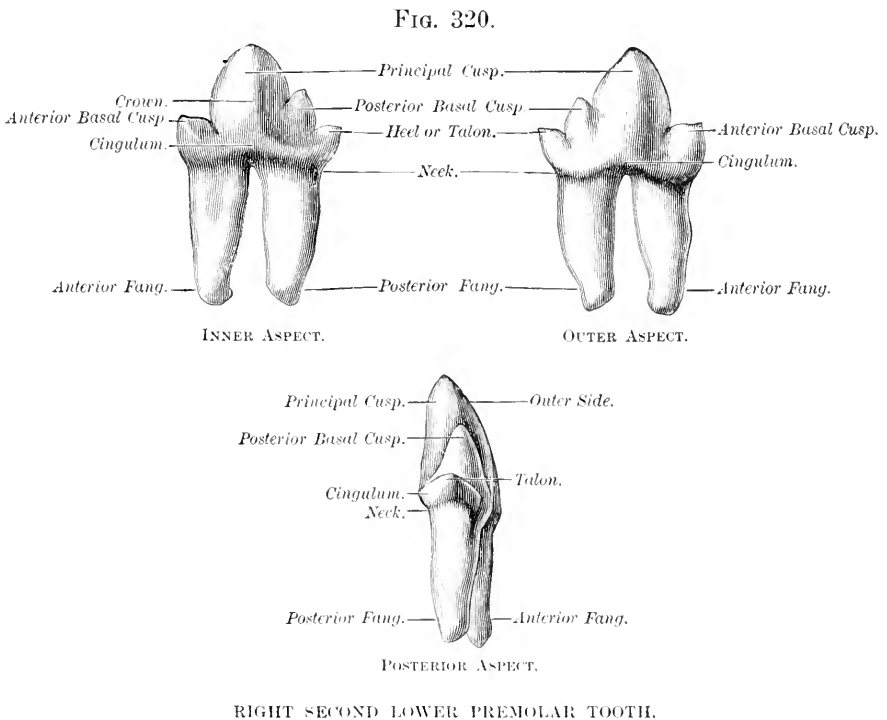


It must be borne in mind when reading works on Comparative Anatomy and Zoology that in the permanent set the premolar and molar teeth are very generally numbered not as they appear in the jaw, but according to what is believed to be their relative value

in a typical mammalian dentition, which is regarded as containing forty-four teeth:  $i \frac{3}{3}$ ,  $c \frac{1}{1}$ ,  $pm \frac{4}{4}$ ,  $m \frac{3}{3}$ . Inasmuch as the cat has but three upper premolars, the missing one cannot have been between the premolars and the molars. Its first upper premolar, therefore, corresponds with the second upper premolar of the typical dentition, the second with the third, and the third with the fourth. In the lower jaw the first premolar corresponds with the third typical premolar, and the second with the fourth. The premolar teeth are sometimes numbered from behind forward; thus what we call the third upper premolar is known as the first, the second as the second, the first as the third. In the following descriptions I have thought it best to number the teeth in their natural order, without regard to theoretical relationship.

The premolars and molar teeth taken together constitute the **cheek-teeth**.

If we examine the second lower premolar (Fig. 320) we observe



that it is divided into two principal parts, (1) the **crown**, which projects above the gum and is covered with hard, glistening enamel, and (2) the roots, or **fangs**, which are contained in the alveoli of the jaw and are covered with a rough substance resembling bone, known as

**cementum.** Where the fangs join the crown is a faint constriction, the **neck**.

The **crown** as a whole is conical in shape, but strongly compressed from side to side. It is limited at its base by a well-marked ridge of enamel, the **cingulum**,<sup>1</sup> which completely encircles the tooth above the neck and thus protects the edge of the surrounding gum. The base of the crown is broader behind than in front; the outer side is usually more convex from before backward than the inner side. The cingulum rises in front and behind and arches over the interval between the two fangs. The central triangular elevation of the crown is known as the **principal cusp**, or protoconid; its inner and outer surfaces, sometimes called the lingual (tongue) and buccal (cheek) surfaces respectively, are both convex from before backward; the inner surface is usually marked by a vertical median ridge. The outer surface is more convex from above downward than the inner surface. The crown presents sharp anterior and posterior borders.

The **posterior border** is interrupted a little below the middle by a transverse notch, which produces a second smaller cusp, the **posterior basal cusp**, or metaconid. Behind this cusp is a second transverse incision, beyond which the cingulum is elevated into a small cusp known as the **talon**, or heel.

The **anterior border** is more vertical; it is notched at its lower end to produce a small **anterior basal cusp** which sometimes is merely an elevation of the cingulum. The inner side of the crown exhibits depressions below the notches which define the middle central cusp.

The length of the **fangs** is slightly greater than the height of the crown; the antero-posterior diameter of both and the transverse diameter of each are less than the diameters of the crown at its base. The fangs are oval in cross-section, and their tips, although often enlarged, are smaller than their bases; of the two the anterior is usually the smaller.

The tooth is formed of a peculiar hard tissue, the **dentine**, which encloses a pulp cavity filled with the dental pulp supplied by vessels and nerves through the foramina in the apices of the roots. The dentine is covered on the crown with enamel, and on the roots with bone-like cementum. While a tooth is growing, the pulp cavity

<sup>1</sup> A girdle.

is widely open at the apex of each fang. As growth ceases, the fang tapers to a point which is pierced only by a fine opening.

Having thus gained an idea of the general structure of a typical tooth, the student is prepared to study the entire series, beginning with the permanent set.

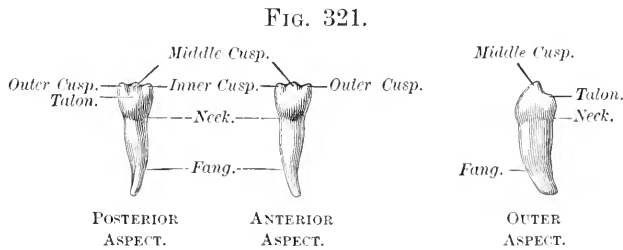
#### THE PERMANENT TEETH.

$$\text{Formula: } i \frac{3}{3}, c \frac{1}{1}, pm \frac{3}{2}, m \frac{1}{1}.$$

The **incisors** are the six small teeth planted transversely in the premaxillary bones and the six small teeth which are opposed to them in the mandible below. Each has a single fang, which is relatively long, compressed laterally, and curved backward.

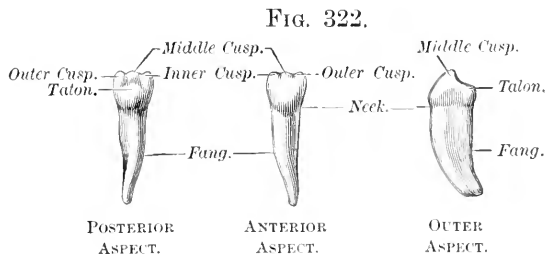
Of the **upper incisors**, the first, or inner, is the smallest, and the third, or outer, the largest.

The crown of the **first upper incisor** (Fig. 321)<sup>1</sup> is broader in



RIGHT FIRST UPPER INCISOR TOOTH.

front than behind, and compressed from before backward. The anterior surface is slightly convex, and may be pitted. The posterior



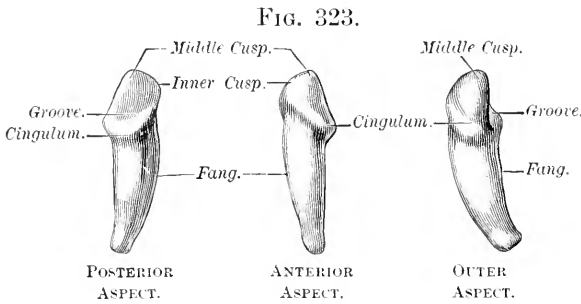
RIGHT SECOND UPPER INCISOR TOOTH.

surface is divided by a transverse groove into a higher anterior part and a lower posterior part. The anterior chisel-like part when unworn exhibits three cusps, whereof the middle cusp is slightly larger than

<sup>1</sup> For convenience of study and comparison the upper teeth are represented in the figures with their crowns uppermost.

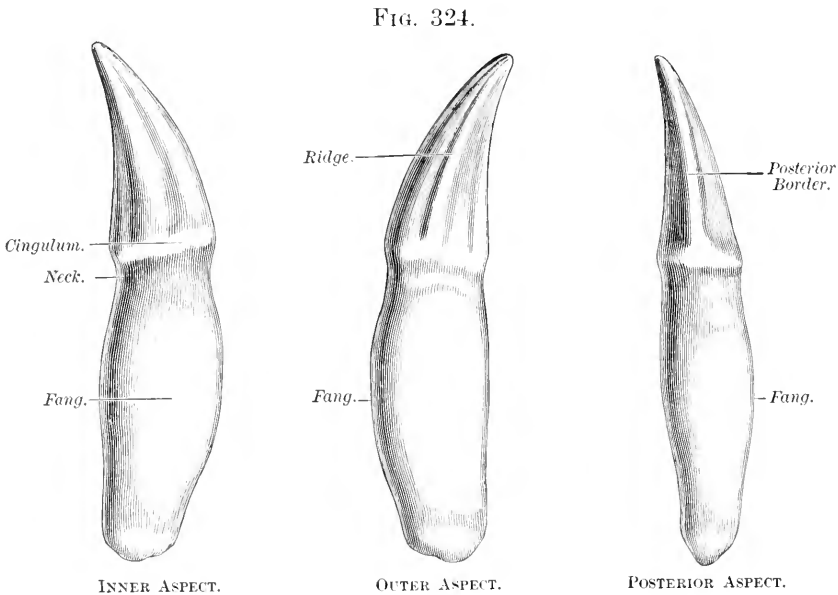
the cusps on either side, which are connected with the posterior part, or talon, by lateral elevated lines.

The crown of the second upper incisor (Fig. 322) is broader than that of the first; the middle cusp appears to be nearer the inner angle than the outer angle.



RIGHT THIRD UPPER INCISOR TOOTH.

The third upper incisor (Fig. 323) is much larger than the others. Its crown is more conical, comprising the central cusp, with a mere trace of an inner cusp. Its outer border is long and straight; the inner border is short and arcuate. The anterior surface presents a



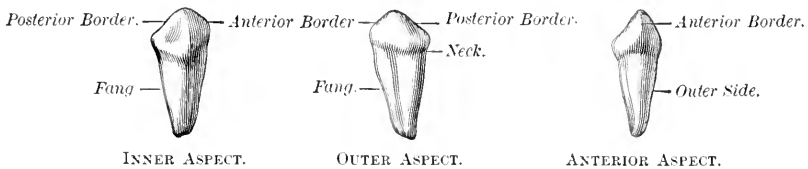
RIGHT UPPER CANINE TOOTH.

smaller inner part and a larger outer part which faces laterally. The transverse groove on the posterior surface slopes obliquely outward and upward to accommodate the lower canine, which passes behind and

lateral to this tooth. The broad fang curves upward, outward, and backward.

The **upper canine** (Fig. 324) is a strong, pointed, and curved tooth. The single subconical fang is longer than the crown; the cingulum is not well marked. The crown presents a small inner surface, which is slightly concave from above downward and convex from before backward; a larger outer surface, which is convex in both directions, but more strongly from before backward; a gently arcuate and rounded anterior border, and a sharper emarginate posterior border. The outer surface is usually marked by vertical grooves, along one of which the tooth often breaks when drying.

FIG. 325.

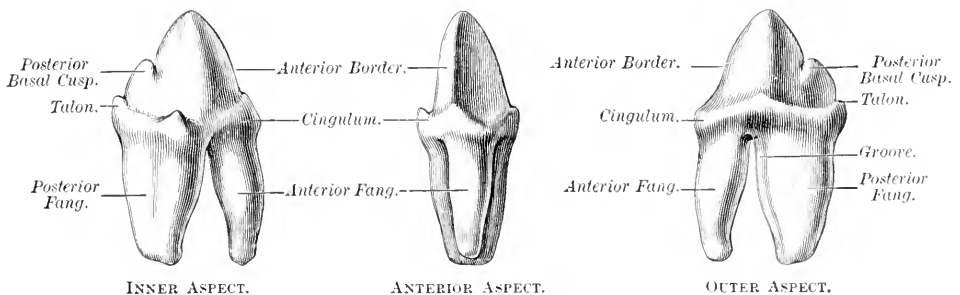


RIGHT FIRST UPPER PREMOLAR TOOTH.

The **first upper premolar** (Fig. 325) has a single fang, supporting a small laterally compressed conical crown; it may have two fangs, in which case the crown has greater antero-posterior length and may have a small posterior cusp.

The point of the single cusp is anterior to the middle of the crown. The shorter rounded anterior border is directed toward the inner side of the anterior end of the base; the longer posterior border is sharper,

FIG. 326.

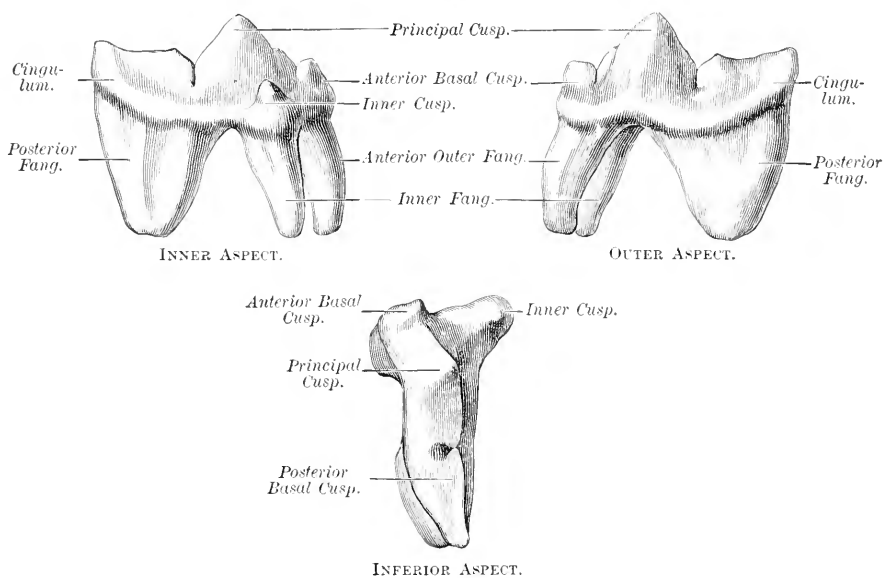


RIGHT SECOND UPPER PREMOLAR TOOTH.

and, near the cingulum, separates two depressions, whereof the inner is the deeper. The outer surface is more strongly convex from above downward than is the inner surface.

The **second upper premolar** (Fig. 326) resembles the second lower premolar already described; the small anterior cusp of the crown is usually wanting, and, when present, is an inconspicuous elevation of the inner anterior end of the cingulum. The principal cusp, or protocone, and the posterior basal cusp, or tritocone, are distinct. The outer surface of the crown is that one which is strongly convex from before backward, and marked by the median vertical ridge. The inner surface is flatter, and its posterior part, which shears against the anterior part of the outer surface of the second lower premolar, often exhibits evidence of wear. The borders are directed toward the inner side of the ends of the base. The cingulum is swollen on the inside behind the middle, and sometimes presents at this point a distinct cusp, or deuterocone, borne on a separate slender inner fang. The posterior fang is much stronger than the anterior, and is prismatic on cross-

FIG. 327.



RIGHT THIRD UPPER PREMOLAR TOOTH.

section, because in addition to the outer and inner surfaces it presents opposite the anterior fang a third narrow and deeply grooved surface, which faces outward and forward; the inner surface often exhibits a wide vertical groove.

The **third upper premolar** (Fig. 327) is twice as large as the second premolar. Its broader anterior end has two transversely placed fangs; the greater part, however, is supported by a single large posterior fang.

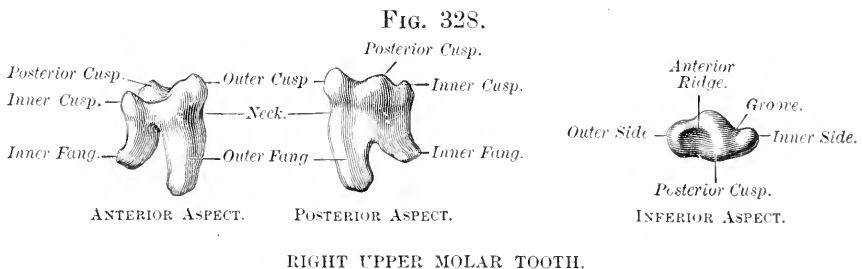


The crown is a cutting blade which forms with the lower molar a scissors-like shearing apparatus; hence both these teeth are termed the *sectorial*,<sup>1</sup> or *carnassial*,<sup>2</sup> teeth.

The cutting blade of the upper sectorial is composed of a principal cusp, or protocone, and a greatly enlarged posterior basal cusp, or tritocone, which is separated from the principal cusp on the outer side by a narrow vertical cleft and on the inner surface by a deep excavation. It presents a sharp horizontal cutting edge, which begins behind at the prominent posterior end of the cingulum and is directed forward and inward to the point of the principal cusp, whence it is continued upward and outward as a sharp anterior border. The inner surface of the two cusps is flat or slightly convex from before backward, and shears against the outer surface of the lower sectorial. The outer surface of the posterior basal cusp is slightly concave, and slopes downward and inward. The outer surface of the principal cusp is strongly convex antero-posteriorly.

The broad anterior part of the crown is occupied by two small conical cusps. Of these, the outer and smaller, the anterior basal cusp or protostyle, is connected with the anterior border of the cutting blade and is supported by the anterior outer fang. The inner and larger cusp, the deuterocone, is distinct, and supported by the larger inner fang.

The anterior fangs are directed upward parallel with each other. When the tooth is in the jaw the outer fang is in advance of the inner. Both are oval in transverse section, but are placed at such an



angle to each other that the long diameters of the ovals if produced would meet behind under the middle of the crown.

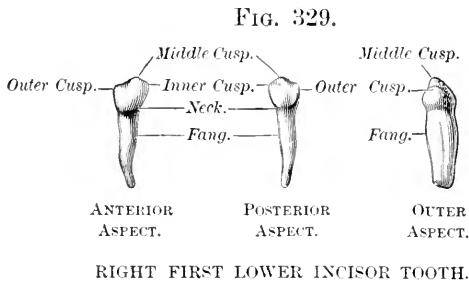
The posterior triangular fang is strongly flattened from side to side, and carries the protocone and the tritocone. The cingulum is well marked and strongly curved toward the crown behind.

<sup>1</sup> From *secare, sectum*, to cut.

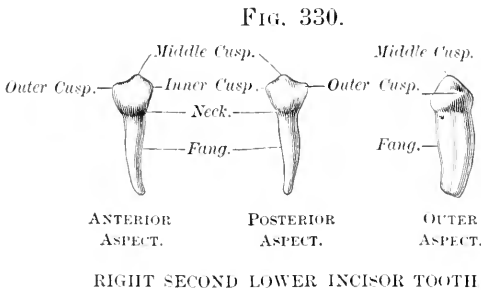
<sup>2</sup> From *caro, carnis*, flesh.

The upper molar (Fig. 328) is a very small, two-rooted tooth, placed transversly to the alveolar border, close behind and in contact with the posterior end of the sectorial.

The transversely oval crown differs from the crowns of all the other teeth in presenting a small tubercular grinding surface in place of the sharp triangular cusp. The outer end of the crown is wider and more prominent than the inner end. The posterior border exhibits near the middle an inconspicuous tubercle, from which a ridge curves forward and outward along the anterior border to an outer cusp. Behind the ridge is a crescentic depression. The inner slightly tubercular end of the crown is separated from the middle tubercle by a



shallow groove, which notches the posterior border and slopes upward at the anterior border. This may be regarded as the condition of the crown when the tooth is fully developed and unworn; often, however, the tooth is rudimentary or the peculiar features of the crown have been worn away. The fangs are variable in size; the outer appears to be constantly the larger. The anterior edge of the crown wears against the posterior surface of the lower molar (Fig. 337).

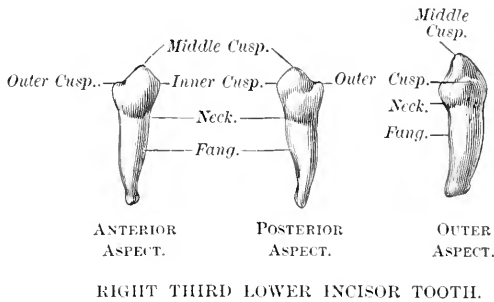


The lower incisors closely resemble the corresponding upper teeth; they are smaller, however, and the posterior surface of the crown is not crossed by the transverse groove.

The **first lower incisor** (Fig. 329) is the smallest of the three; it is, therefore, the smallest tooth of the entire permanent series.

The **second lower incisor** (Fig. 330) is distinctly larger, with a broader crown and a stouter fang. The cutting edges of these teeth present three small cusps; the middle cusp is nearer the inner angle, hence the edge appears to slope downward and outward. Inasmuch as the lower incisors bite behind and between the upper incisors, the anterior surface and the larger outer part of the cutting edge may exhibit signs of wear.

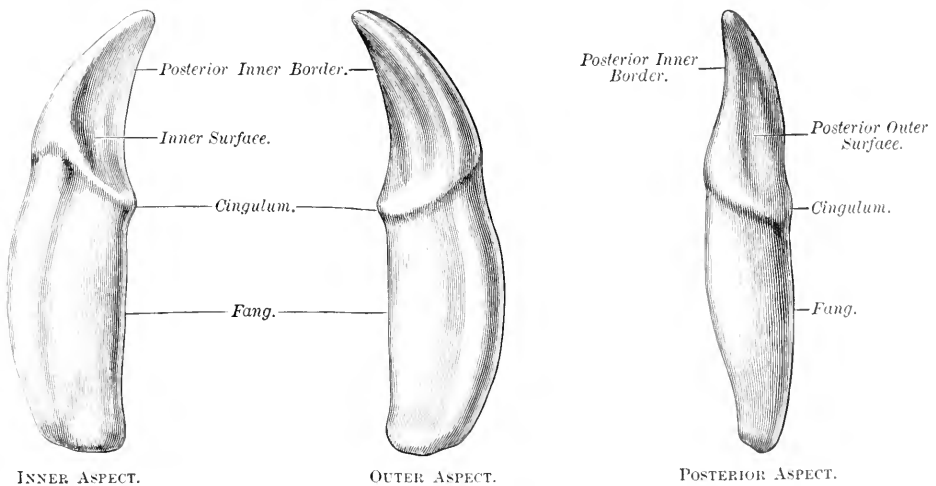
FIG. 331.



RIGHT THIRD LOWER INCISOR TOOTH.

The crown of the larger **third lower incisor** (Fig. 331) is chisel-shaped like the rest, and not conical like the corresponding upper incisor. The inner and middle cusps are close together; the outer cusp is small, but very distinct.

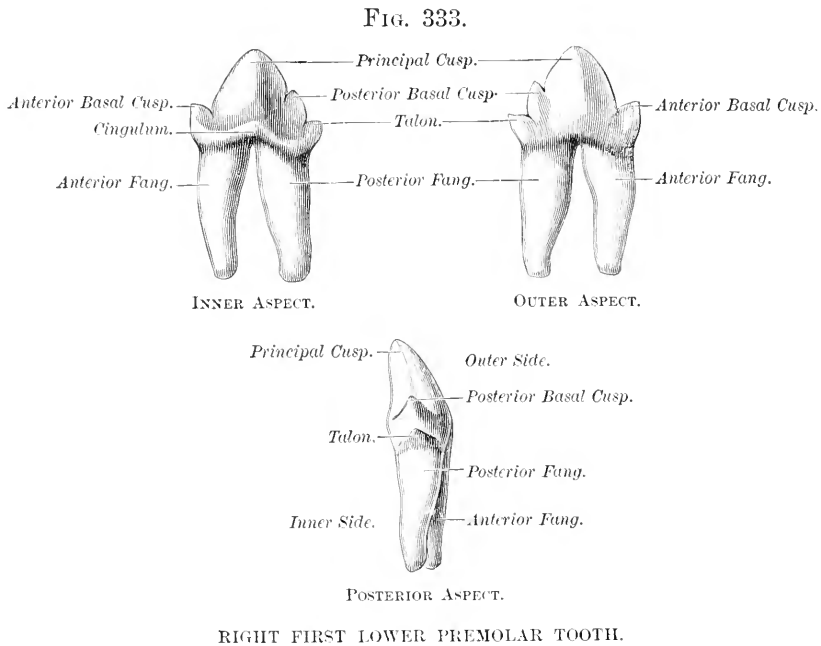
FIG. 332.



RIGHT LOWER CANINE TOOTH.

The **lower canine** (Fig. 332), which is placed close to the incisors, is directed outward and forward as well as upward; it passes in front of the upper incisor and medial to it (Fig. 336).

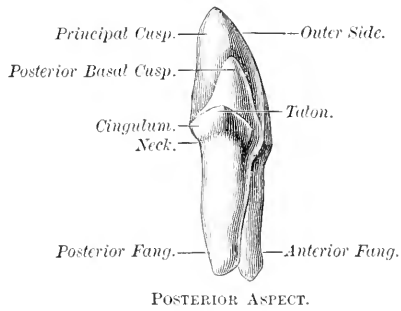
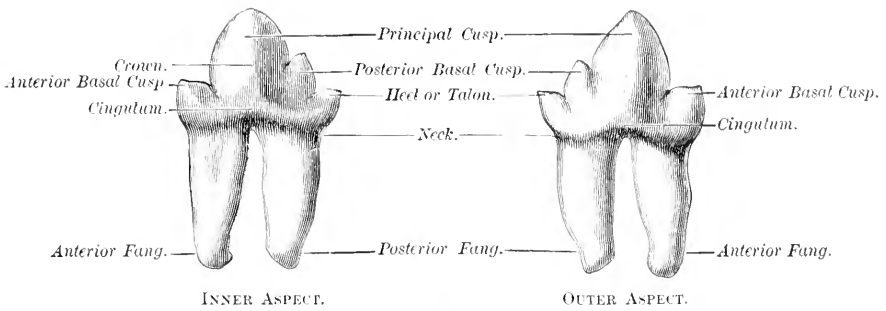
The crown is strongly curved backward, and presents an anterior outer surface, which is convex and ridged; a posterior outer surface, which is twisted, concave from above downward, and slightly convex from side to side; and an inner surface, which is slightly concave from above downward, and almost flat from before backward. The emarginate posterior inner border is sharp, and shears against the anterior border of the upper canine.



The first lower premolar (Fig. 333) is separated from the canine by a long diastema, but is close to the second premolar. It is a much larger tooth than the very small first upper premolar, and closely resembles the second lower premolar; it is smaller, however, and the anterior cusp of the cingulum is less prominent, or may be absent; hence the anterior fang is more slender. It is not unlike a small second upper premolar; its posterior fang, however, is not prismatic. The lower jaw is so much narrower than the upper jaw at this point that the first lower premolar cannot strike the upper teeth.

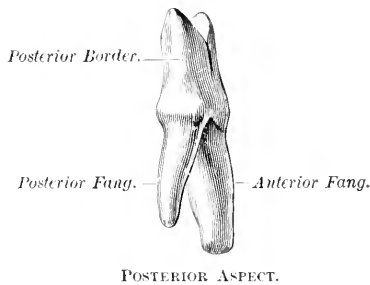
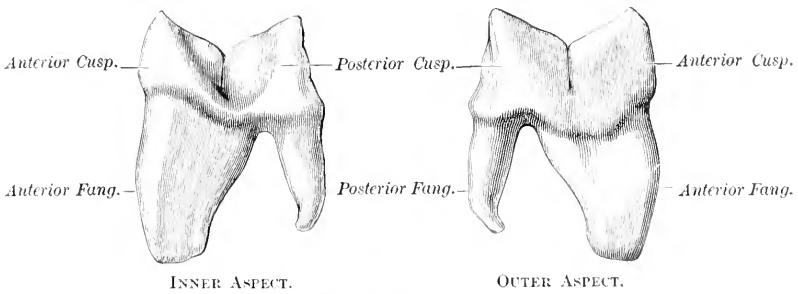
The second lower premolar (Fig. 334) has been already described (page 405). Its prominent anterior cusp and its subequal fangs distinguish it from the corresponding upper premolar. The anterior part of the outer surface of its crown wears against the posterior part of the inner surface of the crown of the upper premolar (Fig. 337).

FIG. 334.



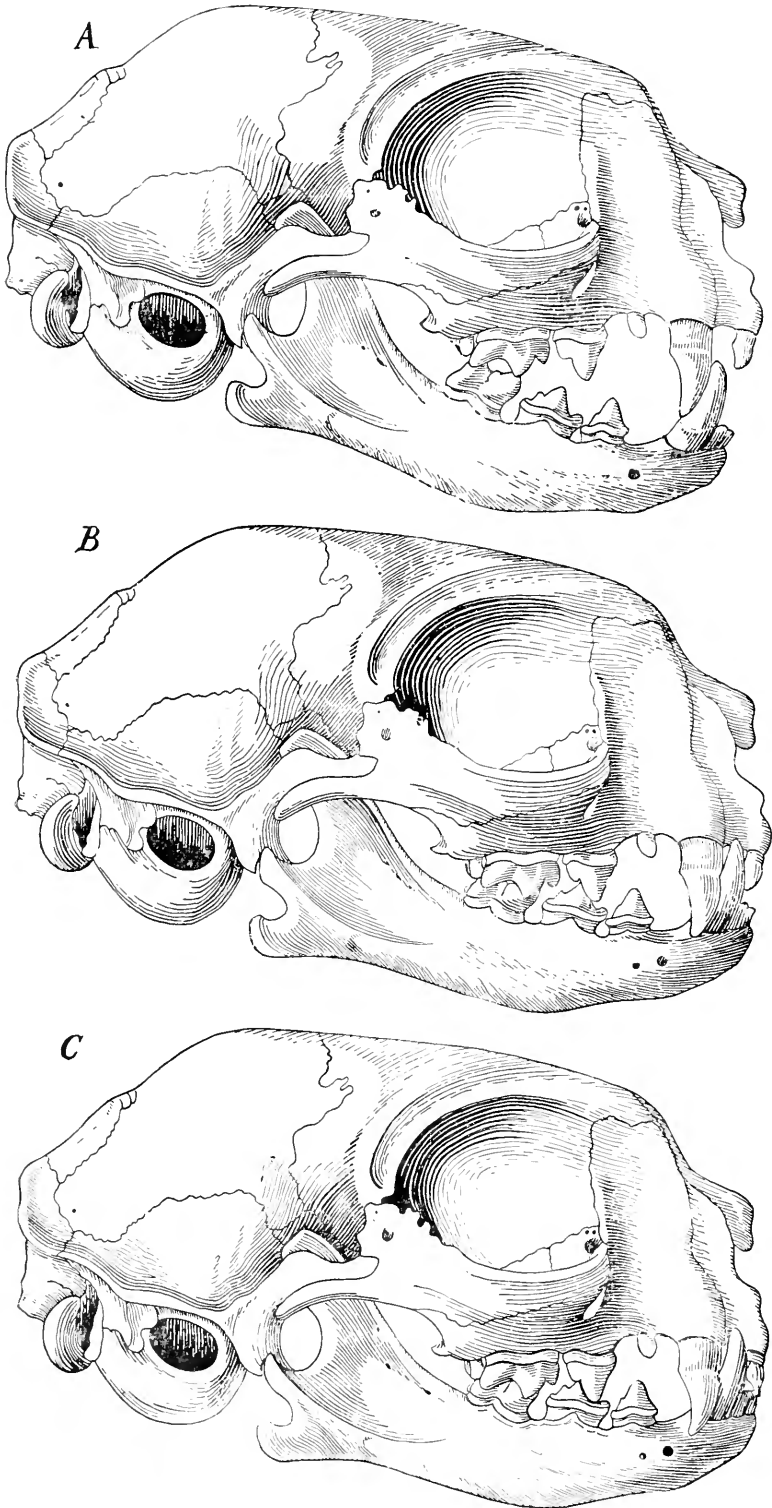
RIGHT SECOND LOWER PREMOLAR TOOTH.

FIG. 335.



RIGHT LOWER MOLAR TOOTH.

FIG. 336.



RELATIONS OF THE UPPER AND LOWER TEETH.

*A*, jaws opened; *B*, jaws almost closed; *C*, jaws closed.

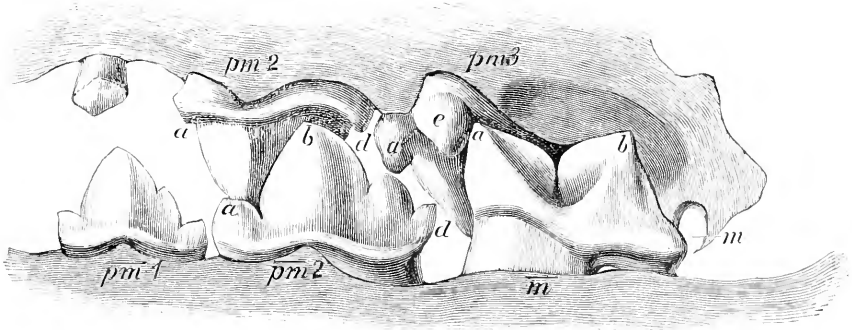
The last tooth in the lower jaw is a true molar (Fig. 335); it has no predecessor in the milk dentition. From its peculiar shape, and because it shears against the upper sectorial or third premolar, it is called the lower sectorial. In form, it resembles a reversed upper sectorial, turned with its posterior end in front, its anterior end, lacking the two small cusps, behind, and the inner surface outward.

The cutting blade of the crown is formed of two nearly equal cusps, the paraconid and the protoconid, which meet in a wide angle. They are separated on the convex outer surface by a vertical fissure, and on the concave inner surface by a deep pit. The anterior and posterior edges of the blade are almost vertical.

The greater part of the crown is supported by the large anterior fang, which is curved and laterally compressed; its tip is truncated and its small posterior surface deeply grooved. The small posterior fang is straight and supports only the back of the tooth.

The lower sectorial is placed slightly obliquely in the lower jaw ;

FIG. 337.



RELATIONS OF UPPER AND LOWER TEETH. INNER ASPECT.

*a*, anterior cusp; *b*, middle cusp; *c*, posterior cusp; *d*, talon; *e*, inner cusp.

the posterior end is near the outer edge of the alveolar border, and the anterior end passes to the inner side of the posterior end of the second premolar. The greater part of the outer surface wears against the inner surface of the cutting blade and of the internal cusp of the upper sectorial; a small posterior external part is concave and is cut by the anterior edge of the small upper molar (Fig. 337).

When the jaws are closed and at rest, the only teeth in contact are the incisors and the canines. The lower incisors, normally, strike behind the upper incisors in such manner that the crowns of the two

internal lower teeth come between the crowns of the two internal upper; the middle lower on each side comes between the internal and middle upper, and the external lower between the middle and external upper. The external upper incisor, therefore, is between the external lower incisor and the lower canine.

The incisors and canines are used for grasping and biting food; cutting is done by the posterior teeth, especially by the sectorials (Fig.

FIG. 338.

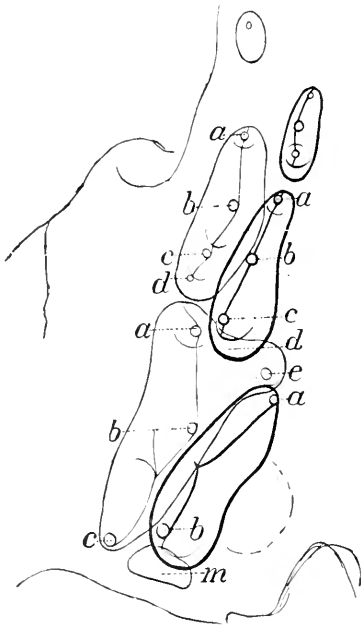


DIAGRAM OF APPPOSITION OF POSTERIOR TEETH.

*a*, anterior cusp; *b*, middle cusp; *c*, posterior cusp; *d*, talon. Heavy outlines show lower teeth; light outlines show upper teeth.

336), near which are inserted the powerful muscles of mastication. The lower back teeth are nearer the middle line of the mouth than are the upper teeth, which they do not touch when the jaws are moved in an absolutely vertical line; hence when the cat chews on one side of the mouth the lower jaw must be brought to that side, that the outer surface of the lower teeth may shear upward and forward against the inner surface of the upper teeth. If, however, the mass of food is very large, we may suppose that at first the lower jaw will be thrown to the opposite side, where the lower teeth will grind directly against the upper. The areas of wear on the back teeth therefore appear to be produced in several ways: namely, by the grinding of hard substances between the teeth, the nearest surfaces of opposite teeth suffering first;

by the wearing of tooth on tooth when softer substances are chewed; and by the wearing of tooth on tooth on the side of the jaw not actively in use in chewing. Inasmuch as the lower jaw articulates with the skull by means of a hinge-joint, the larger posterior teeth come together before the smaller anterior teeth.

The relation between the upper and lower back teeth is shown in Fig. 337; it may be also represented by a diagram (Fig. 338) which exhibits the teeth as viewed from below when the lower teeth are supposed to be transparent. The heavy lines are the outlines of the lower teeth, the light lines the outlines of the upper teeth.



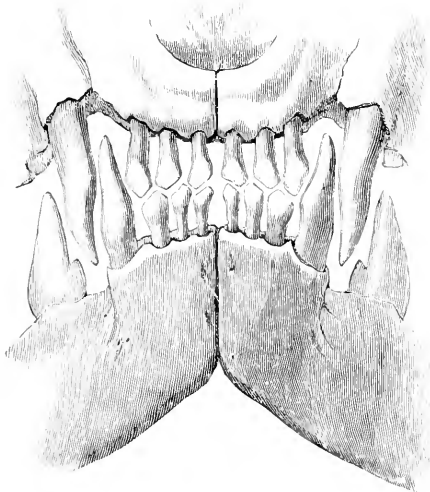
## THE DECIDUOUS TEETH.

$$\text{Formula: } di \frac{3}{3}, dc \frac{1}{1}, dm \frac{3}{2}.$$

The upper deciduous incisors (Fig. 339) are almost exactly like the permanent teeth; they are smaller, and the crowns of the inner and middle appear to be more pointed, owing to the elongated middle cusp.

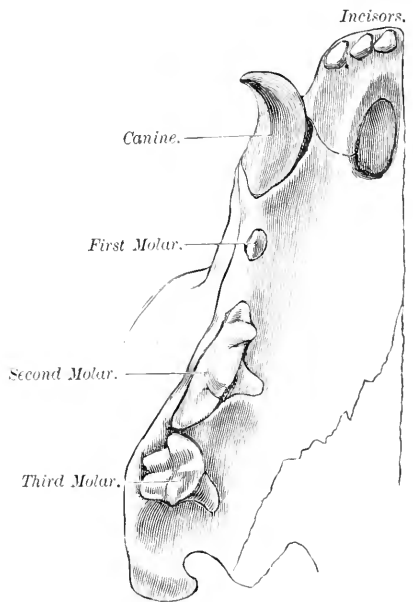
The upper deciduous canines (Figs. 340, 341) are much more slender than the permanent. The crowns are more strongly curved; the posterior borders are so deeply emarginate that the cingulum presents a decided heel. On the anterior border near the base, in very young teeth, is a sharp angle, below which the border is sharp and straight, to cut against the posterior outer border of the lower canine.

FIG. 339.



ANTERIOR DECIDUOUS TEETH.

FIG. 340.

RIGHT UPPER DECIDUOUS  
TEETH. INFERIOR ASPECT.

The first upper deciduous molar (Figs. 340, 341) is a very small tubercle, resembling the permanent tooth.

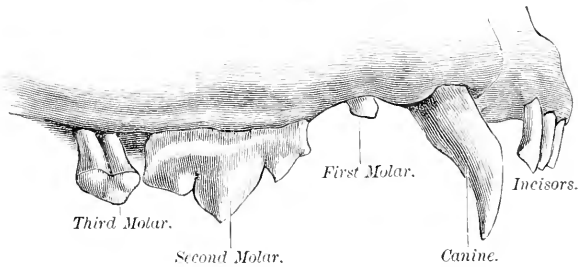
The second upper deciduous molar (Figs. 340, 341) is a sectorial tooth. It differs from the permanent sectorial in general by its smaller size and the acuteness of its cusps. The internal cusp and fang are not at the anterior end, but at the middle of the tooth; the cusp projects but little beyond the gum. The central cusp is very acute; in front of the anterior cusp, which is inclined inward, is a distinct

and sharp outer cingular elevation. This tooth is replaced by the permanent second premolar, which is not a sectorial tooth.

The second upper deciduous molar (Figs. 340, 341) is like the permanent molar, but more complicated. It has three slender fangs, whereof two are external and close together and one is internal and widely divergent.

The crown is triangular; broad along the anterior inner edge and narrow without and behind. The outer anterior angle is the most

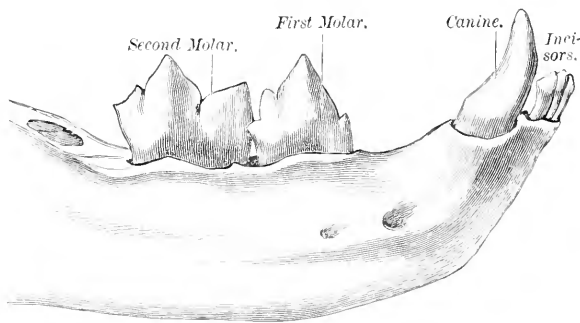
FIG. 341.



RIGHT UPPER DECIDUOUS TEETH. OUTER ASPECT.

prominent, and is nearer the outer side of the jaw than is the outer posterior angle. The inner angle presents an inconspicuous cingular cusp, which is separated by a groove from the outer and more important part of the crown. This part is crescentic; on the inner arcuate edge is a tubercle, which is connected by sharp curved lines with the pointed

FIG. 342.



RIGHT LOWER DECIDUOUS TEETH. OUTER ASPECT.

external angles and by a middle straight line with the emarginate external border. Between the lines the surface is excavated.

The lower deciduous incisors (Figs. 339, 342) are very small; their crowns present three cusps, with the middle and external cusps

more distinct. When unworn, the middle cusp appears to be longer than the corresponding cusp of the permanent teeth.

The **lower deciduous canine** (Figs. 342, 343) is more vertical than the permanent tooth; it resembles the upper deciduous canine, but the angle on the anterior border is often developed into a distinct cusp, which strikes against the outer side of the crown of the third upper incisor.

The **first lower deciduous molar** is the tooth which is posterior to the lower canine and separated from it by a long diastema, where the jaw is excavated for the passage of the upper canine. It resembles the permanent first premolar which replaces it. It is smaller, however, and its crown is more acute and more deeply incised; the talon is well developed.

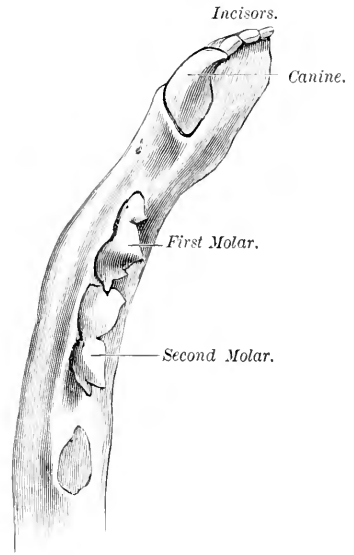
The **second lower deciduous molar**, the last in the jaw, differs from the premolar which replaces it in being a sectorial tooth. It closely resembles the permanent sectorial; its crown, however, presents a more elevated posterior cusp on the cutting blade, behind this a smaller cusp, and a decided talon on the cingulum.

The relations between the upper and lower deciduous teeth are somewhat different from the relations between the upper and lower permanent teeth. The transverse width of the row of upper incisors is often very little greater than the width of the row of lower incisors; hence the lower canines are more vertical. In some cases, at least, the lower incisors bite in front of the upper. The inner surface of the large upper sectorial wears against the outer surfaces of both lower molars; the posterior outer part of the lower sectorial is sheared by the prominent part of the anterior border of the tubercular third upper molar.

#### ERUPTION OF THE TEETH.

The deciduous teeth begin to appear through the gums at about the end of the second week after birth. They may be delayed, however, and the order of their appearance is undoubtedly subject to

FIG. 343.



LEFT LOWER DECIDUOUS  
TEETH. SUPERIOR ASPECT.

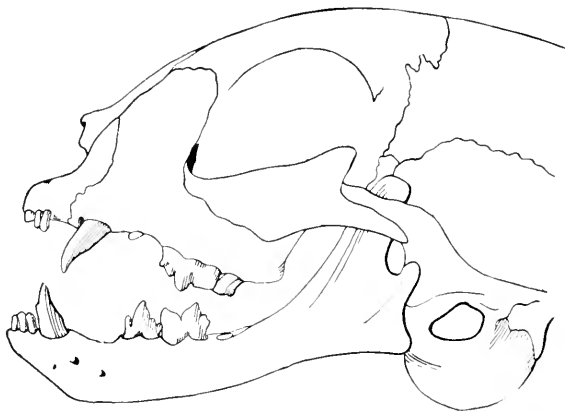
variations. The following observations on the eruption of the teeth in animals of known ages, although correct in themselves, may not hold good for all specimens.

At seven days after birth no teeth have appeared and none can be distinctly felt through the gums. After the gums have been cut away the upper incisors and canines can be seen in the alveolar border.

At eleven days no teeth have come through the gums; the first and second upper incisors, however, can be plainly felt. After the gums have been cut away the first and second upper incisors and the points of the third incisor and of the canine protrude through the bony alveolar border.

At thirty days all the teeth, except the first upper molars, have appeared through the gums. There are then visible about one-third of the upper canines and slightly more of the lower canines, one-half of the first lower molar, the points of the upper sectorial, and one point of the lower sectorial. After the gums have been cut away the teeth are seen to be clearly through the alveolar border; the small first upper molar is just appearing.

FIG. 344.



ERUPTION OF PERMANENT FIRST UPPER INCISOR  
TOOTH.

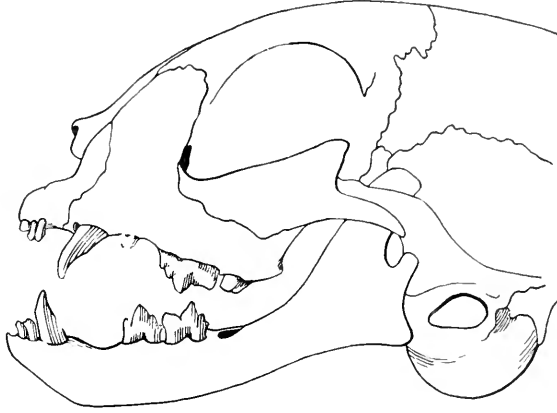
At forty-four days the teeth protrude much further; the first upper molar is, however, still hardly apparent.

At sixty days the deciduous dentition is complete.

I have not been able to fix precisely the date of the eruption of the first permanent tooth. The skull of a kitten ninety days old exhibits all the deciduous teeth firmly in position. In the skull of a kitten one hundred and thirteen days old, the permanent first and second

upper and lower incisors have replaced the corresponding milk teeth; in the skull of another kitten of the same litter, one hundred and twenty days old, all the permanent incisors have appeared. It may

FIG. 345.

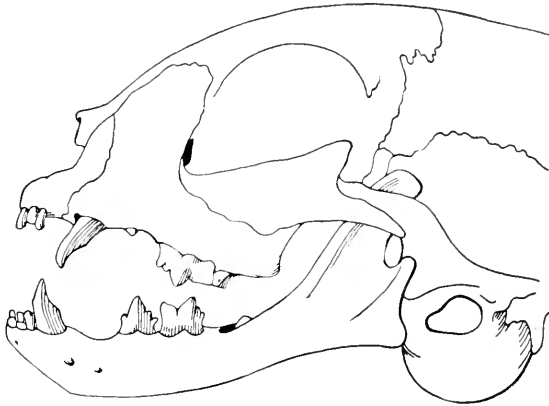


ERUPTION OF PERMANENT FIRST UPPER INCISOR TOOTH,  
AND LOSS OF DECIDUOUS FIRST LOWER INCISOR.

be safe, therefore, to assume that the date for the eruption of the first permanent tooth is near the end of the fourteenth week after birth.

The first permanent tooth to appear is the first, or internal, upper

FIG. 346.



ERUPTION OF PERMANENT SECOND UPPER INCISOR TOOTH;  
PERMANENT FIRST UPPER INCISOR IN POSITION; PER-  
MANENT FIRST AND SECOND INCISORS PUSHING  
OUT CORRESPONDING DECIDUOUS TEETH.

incisor (Fig. 344). In some cases an interval of time may elapse between the loss of a tooth and the appearance of its successor; thus in one specimen examined (Fig. 345) the first lower incisor was lost while the first upper incisor was coming down. As a rule, however,

the deciduous incisors are pushed out by the permanent teeth which erupt behind them.

FIG. 347.



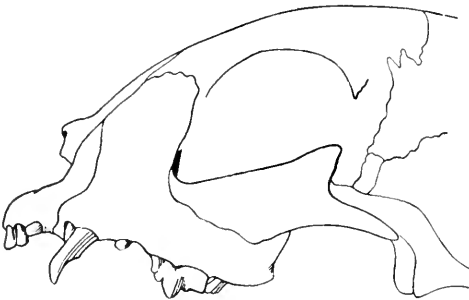
ERUPTION OF PERMANENT THIRD LOWER INCISOR AND LOWER MOLAR TEETH; PERMANENT FIRST AND SECOND UPPER AND LOWER INCISORS IN POSITION.

The second upper incisor appears shortly after the first; at about the same time the permanent first and second lower incisors push out the corresponding milk teeth (Fig. 346).

The third lower incisor now pushes out the deciduous tooth, and the posterior part of the permanent lower molar rises through the gum (Fig. 347). If the gum be cut away at this stage, in some specimens the permanent upper molar and the point of the first premolar will be visible.

The third upper incisor appears next, and at about the same time also the small first upper premolar (Fig. 348). At this stage after the gum has been removed the permanent canines are visible.

FIG. 348.



ERUPTION OF PERMANENT THIRD UPPER INCISOR AND FIRST UPPER PREMOLAR TEETH, FIRST AND SECOND PERMANENT UPPER INCISORS IN POSITION; IN SKULL ONE HUNDRED AND TWENTY DAYS AFTER BIRTH.

After the permanent upper canine has descended for some distance in front of the deciduous canine, and after the permanent molar is in position, the second and third upper premolars begin to push out the second and third milk molars (Fig. 349). The second pre-

molar appears in the interval between the anterior and internal fangs of the deciduous sectorial. The principal cusp of the permanent

sectorial descends above the third deciduous molar, between its external and internal fangs, and thus forces it directly downward; the anterior cusp of the permanent sectorial appears just internal to the posterior part of the cutting blade of the deciduous sectorial; and the internal cusp behind and medial to its internal fang.

The permanent upper canine and sectorial are in place before the milk sectorial is lost and before the second upper premolar is fully grown (Fig. 350).

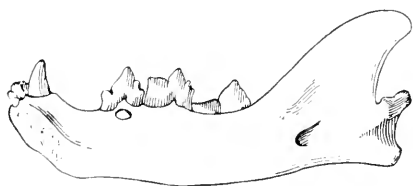
While the permanent upper canine is descending, the lower permanent canine pushes out the deciduous tooth. By this time the permanent lower molar is entirely above the gum and the first lower premolar is coming through the bony alveolar border on the inner side of the corresponding deciduous molar (Fig. 351); as it pushes out this tooth, the second lower premolar, the last tooth, appears on the inner side of the deciduous sectorial. By this order in the succession of the permanent teeth a cat has two sets of sectorial teeth in position at one and the same time; thus is precluded all danger of loss, even temporarily, of this most important element in the dentition.

FIG. 350.



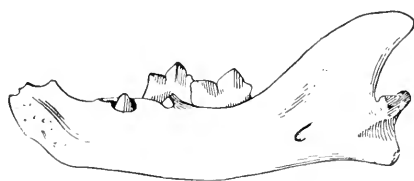
ERUPTION OF SECOND UPPER PREMOLAR TOOTH; SECOND DECIDUOUS MOLAR STILL IN POSITION.

FIG. 351.



ERUPTION OF PERMANENT LOWER MOLAR AND FIRST LOWER PREMOLAR TEETH; DECIDUOUS LOWER MOLARS ALONE REMAINING.

FIG. 352.



ERUPTION OF FIRST AND SECOND LOWER PREMOLAR TEETH; DECIDUOUS SECOND MOLAR STILL PRESENT.

#### DETERMINATION OF THE PERMANENT TEETH.

The upper incisors have a transverse groove across their posterior surfaces. The first and second have three almost equal cusps on their cutting edge, and are so symmetrical that they present no characters whereby the right teeth may be distinguished from the left.

The third incisor has a conical crown and an oblique posterior

groove. If the concave surface of the tooth be held uppermost, the fang away from the student, the longer and straighter border of the crown will be on the side to which the tooth belongs.

The **lower incisors** may be distinguished from the upper by the absence of the posterior groove; the third from the others by the distinct outer cusp. If the tooth be held with the concave side uppermost, the cutting edge toward the student, the more prominent part of the cutting edge will be on the side to which the tooth belongs.

The **upper canine** may be distinguished from the lower by its straighter and relatively longer crown. If the flatter surface of the crown be held uppermost, the fang away from the student, the straight border of the crown will be on the side to which the tooth belongs.

The **lower canine** differs from the upper by its shorter, more strongly curved crown. If the concave posterior border of the crown be held uppermost, the fang away from the student, the tip of the crown will curve toward the side to which the tooth belongs.

The **first upper premolar** may be known by its small size and its triangular crown. If the flatter side of the crown be held uppermost, the fang away from the student, the longer border of the crown will be on the side to which the tooth belongs.

The **second upper premolar** may be distinguished by its larger prismatic posterior root. If the side which has the convexity in the cingulum be held uppermost, the fangs away from the student, the large fang will be on the side to which the tooth belongs.

The **third upper premolar** has three fangs and a cutting blade. If the flat side of the cutting blade be held uppermost, the fangs away from the student, the large fang will be on the side to which the tooth belongs.

The single **upper molar** is readily distinguished by its transversely broad and flat crown and its two fangs. If the prominent outer end be held uppermost, the fangs away from the student, the curved crest on the crown from the middle to the outer end will be on the side to which the tooth belongs.

The **first lower premolar** differs from the second in its smaller size and in the less development of the posterior part of the crown; it differs from the second upper premolar in the almost equal size of its fangs. If the side of the crown which is more convex from above downward and flatter from before backward be held uppermost, the



fang away from the student, the posterior basal cusp will be on the side to which the tooth belongs.

The **second lower premolar** so closely resembles the first that it may be distinguished from the other teeth in the same manner. It is larger than the first, and the secondary cusps are more strongly developed.

The **lower molar** has two fangs and a cutting blade. If the flat surface of the blade be held uppermost, the fangs away from the student, the small fang will be on the side to which the tooth belongs.

#### TABLE OF THE PERMANENT TEETH.

Small teeth with transverse chisel-shaped  
crowns and single fangs.

Posterior surface of crown with trans-  
verse groove.

Edge of crown with three small  
cusps.

Small tooth . . . . . Inner upper incisor.

Larger tooth . . . . . Middle upper incisor.

Crown more conical, posterior  
groove oblique . . . . . Outer upper incisor.

Posterior surface of crown not grooved.

Crown with three cusps, soon worn  
away.

Smaller tooth . . . . . Inner lower incisor.

Middle-size tooth . . . . . Middle lower incisor.

Larger tooth, outer cusp  
distant and distinct . . . . . Outer lower incisor.

Long teeth with conical curved crowns and  
single fangs.

Crowns straighter, larger tooth . . . . . Upper canine.

Crowns more curved, smaller tooth . . . . . Lower canine.

Teeth with laterally compressed crowns.

Small tooth with simple triangular crown  
and one fang . . . . . First upper premolar.

Larger teeth with central large cusp,  
posterior basal cusp, and two serial  
fangs.

Posterior fang large, prismatic; anterior cingular cusp absent or obscure . . . . .	Second upper premolar.
Fangs subequal, well marked ante- rior cusp.	
Smaller tooth, secondary cusps less marked . . . . .	First lower premolar.
Larger tooth, secondary cusps well developed . . . . .	Second lower premolar.
Teeth with crowns narrowed to cutting blades.	
Three fangs . . . . .	Third upper premolar.
Two fangs . . . . .	Lower molar.
Small tooth with transverse, flat, tubercular crown and two variable transverse fangs .	Upper molar.

#### VARIATIONS IN THE TEETH.

The abnormalities of the teeth may be classified as :

(1) Variations in **size**, shown in the crown or in the number of fangs.

(2) Variations in **number**, shown in the absence of a tooth or by supernumerary teeth.

(3) Variations in **form**, due to a malformation which may be single, as confined to one tooth, or double, by the fusion of two teeth.

(4) Variations in **position** of the teeth in the jaws.

More than one kind of variation may be shown by a single tooth, or several teeth in the same jaw may be abnormal either in the same direction or differently.

In the following paragraphs I have arranged the variations of each tooth by themselves, and have included the observations of Hensel<sup>1</sup> and Bateson.<sup>2</sup>

**Incisor Teeth.**—No variations have been observed in the incisors of the cat; they probably exist, inasmuch as Bateson records the occurrence of two extra upper premaxillary teeth in a specimen of *Felis lynx*, and an absence of at least one incisor in several other species.

**Canine Teeth.**—The canines appear to be constant. I have seen

<sup>1</sup> Morphologisches Jahrbuch, 1879, v. p. 552.

<sup>2</sup> Materials for the Study of Variation, 1894, pp. 223–226.

no true variation, merely some abnormalities due to wear and disease. Bateson describes a tiger's skull with two canines on the right side, both of large size and in the same socket. The anterior was the smaller. Neither was a milk tooth.

**First Upper Premolar** ( $\overline{pm\ 1}$ ).—Size. Out of one hundred maxillaries examined, in forty-three this tooth had a single fang, in nine it had two distinct fangs, and in twenty-nine the alveoli were confluent and hence the two fangs were more or less united. In one specimen there were three alveoli, one in front and two confluent behind, but, as the tooth was missing, it is impossible to give any description. Bateson records three cases (presumably out of thirty-eight skulls) of this tooth with double fangs; in one specimen the variation was on both sides, and in another on the right side only.

**Number.** I have found in one hundred maxillaries nineteen examples of absence of the first upper premolar. Hensel notes thirteen examples in two hundred and fifty-two skulls, six times on both sides, once on one side only. Bateson records five cases in thirty-eight skulls, twice on both sides and once on the right side. It must be remembered that the absence of a tooth does not necessarily imply that it was never present; in my own observations I have taken care to include only such examples of the variation as occurred in younger and mature skulls wherein the teeth were well developed and the alveolar borders free from caries.

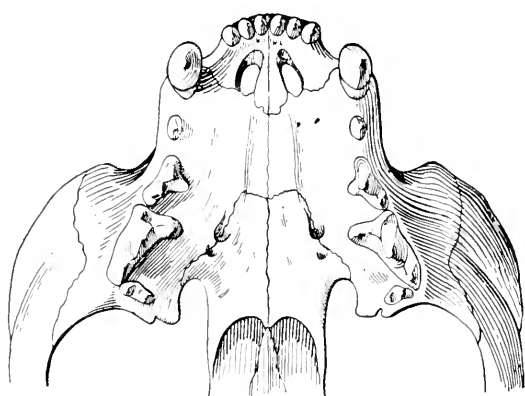
I have only one skull which shows clearly a supernumerary first upper premolar. Bateson describes one case (out of thirty-eight skulls) in which "internal to and rather behind the left  $pm\ 1$  is an almost identical copy of it, though rather smaller. Not a milk tooth." Hensel notes eleven cases of double first premolars in two hundred and fifty-two skulls,—four times on both sides, twice on the right side, and once on the left side.

**Position.** In several specimens in my collection this tooth is placed close to the second premolar. In one maxillary the alveolar border is so short that the first premolar is no more distant from the canine and the second premolar than the second premolar is from the third.

**The Second Upper Premolar** ( $\overline{pm\ 2}$ ).—Size. This tooth varies more than any other in the entire series. In some specimens

the crown is large and presents a decided anterior cingular cusp, in others it is small and the anterior end is perfectly smooth. In nine

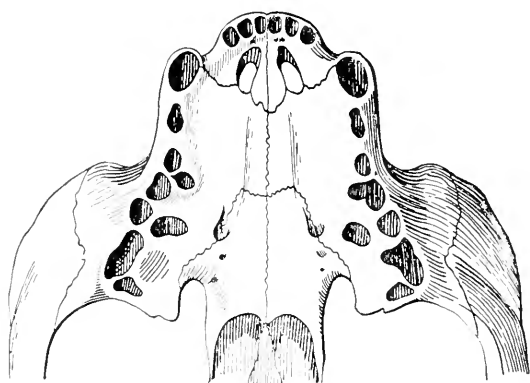
FIG. 353.



A

cases (out of one hundred) the cingulum developed on the inner side a distinct cusp, or deuterocone, which was supported by a separate internal fang (Fig. 353).

**Number.** There is no recorded absence of this tooth. Bateson notes and figures (Fig. 354) a specimen which had "a tooth in the upper jaw closely resembling the second premolar internal to and between it and the carnassial. The internal tooth is slightly smaller than the second premolar."



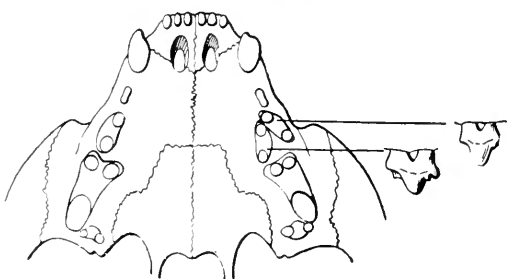
B

A. ABNORMAL UPPER SECOND PREMOLAR TEETH.  
B. THEIR ALVEOLI.

**Form.** In one specimen (Fig. 355) the anterior border of this tooth was longer and more oblique than usual, so that the posterior border was vertical and the apex pointed backward as well as downward. The tooth was

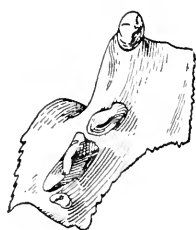
also abnormally placed in the jaw, further than usual in front of the third premolar, with the anterior end of the base of the crown

FIG. 354.



SUPERNUMERARY LEFT UPPER PREMOLAR TOOTH.

FIG. 355.

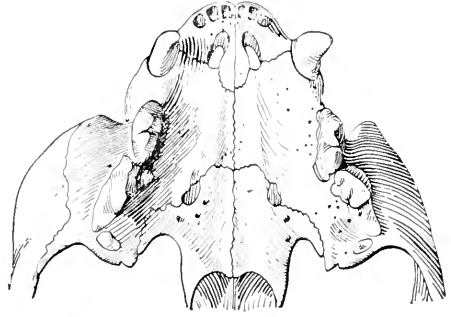


ABNORMAL RIGHT  
SECOND UPPER  
PREMOLAR TOOTH.

directed obliquely inward and forward. The first upper premolar was absent.

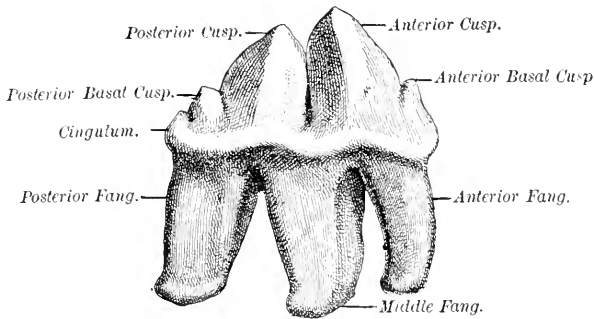
In one specimen in my collection the first premolar is absent and the second upper premolar is double on both sides of the jaw (Fig. 356), presenting a very striking example of the fusion of two teeth, a variation which occurs in human teeth, but until now "rarely, if ever, recorded in other animals." (Bateson.) The left tooth (Fig. 357) is larger than the right tooth. It presents two serially arranged principal cusps separated by a vertical fissure. The anterior cusp has a small basal cusplet near the inner anterior end of the anterior border; the posterior cusp has a small posterior basal cusp and a talon. On the inner side of the cingulum between the two principal cusps is

FIG. 356.

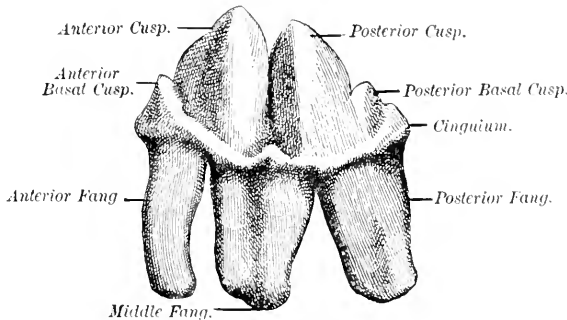


ABNORMAL SECOND UPPER PREMOLAR TEETH.

FIG. 357.



OUTER ASPECT.



INNER ASPECT.

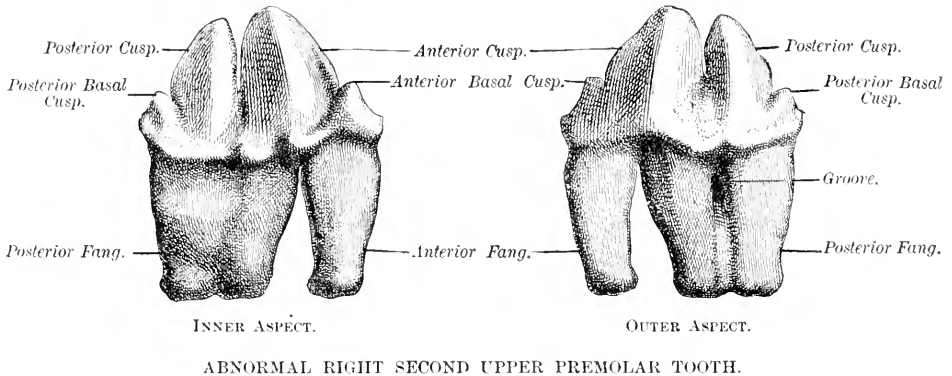
ABNORMAL LEFT SECOND UPPER PREMOLAR TOOTH.

a small cusplet. The crown is carried on three fangs, whereof the middle and posterior are large and prismatic.

The left sectorial is also abnormal (see p. 433).

The right tooth (Fig. 358) is less complicated. The posterior principal cusp is smaller, and the talon is wanting. The posterior fang is united to the middle fang; a groove on the outer aspect indicates the line of attachment.

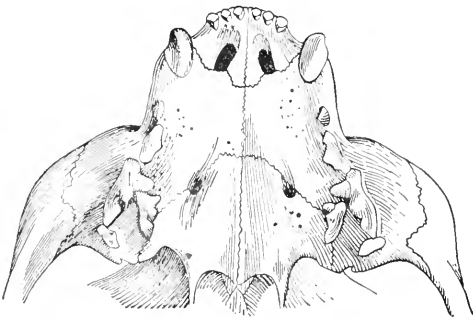
FIG. 358.



**Third Upper Premolar ( $\overline{pm}^3$ ).**—Size. The variations in size appear to be confined to the tooth as a whole. I have no records of the presence of any additional fangs.

**Number.** The upper sectorial is always present. Bateson describes and figures (Fig. 359) a specimen “having a large supernumerary tooth in each upper jaw. The extra tooth was in each case a small but accurate copy of the carnassial tooth of its own side. In each case the extra tooth stood internally to the carnassial tooth, extending from the level of the middle of the carnassial tooth to the level of the middle of the molar.”

FIG. 359.



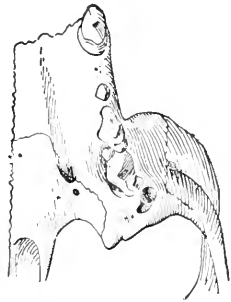
SUPERNUMERARY UPPER SECTORIAL TEETH.

**Form.** I have observed two cases of malformation of the upper sectorial tooth. In the first specimen (Fig. 360) the anterior external cusp (protostyle) was absent, its place being taken functionally by the overlapping talon of the pre-

ceding second premolar. The internal anterior cusp (deuterocone) (Fig. 361) was far in advance of the rest of the tooth, and connected with the border of the principal cusp. The cutting blade consisted of a single protocone with convex sloping outer surface, and a small posterior cusp which turned outward behind to form a small talon. The fangs were fused into a small conical mass. In this specimen the molar was well developed, with two large fangs.

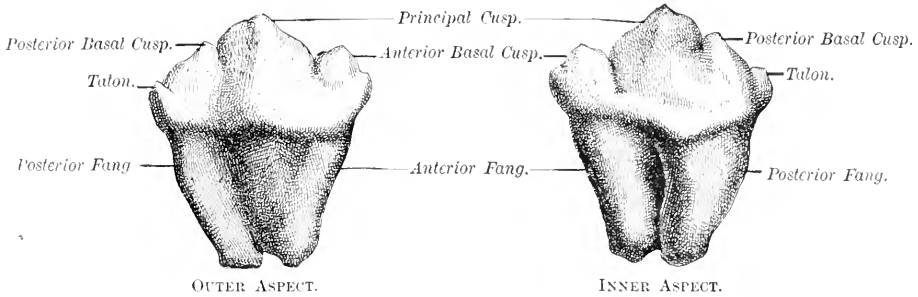
The other abnormal sectorial tooth (Figs. 356, 362) is on the left side of the specimen with the abnormal second premolar teeth. Here the protostyle is large and overlaps the talon of the preceding tooth; the deuterocone is reduced to a cingular tubercle which is not carried on a separate fang. The anterior border of the cutting blade

FIG. 360.



ABNORMAL LEFT UPPER SECTORIAL TOOTH.

FIG. 361.



ABNORMAL LEFT UPPER SECTORIAL TOOTH.

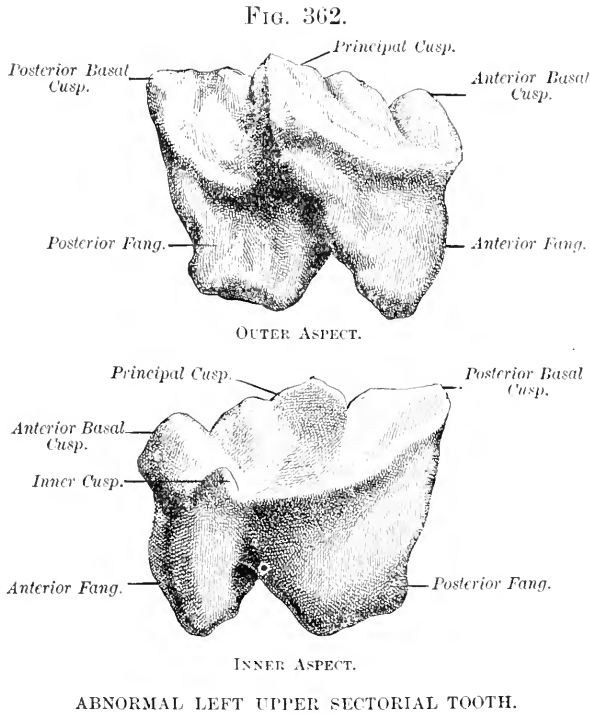
is almost horizontal, and notched to form a second small intermediate cusp. The outer side of the blade shows signs of caries.

Not infrequently the sectorial, while in other respects normal, presents on the anterior border of the cutting blade a very small additional cusplet (Fig. 327).

**The Upper Molar ( $\overline{m}$ ).—Size.** The molar is very variable in size and in the distinctness of the markings on its crown. Out of one hundred specimens, in twenty-one it had a single fang; in thirty, two fangs; and in forty-four the two fangs were more or less coalesced.

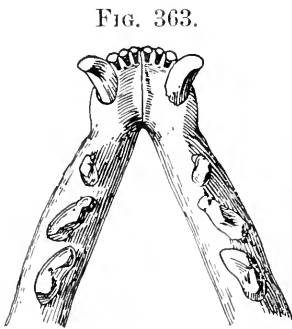
**Number.** No cases of supernumerary upper molars have been reported. It was absent in four maxillaries out of the one hundred I examined. Hensel notes one case only.

**First Lower Premolar** ( $\frac{\text{---}}{\text{pm } 1}$ ).—Size. The variations in size are not especially noteworthy. It appears always to have two fangs. It is interesting to observe that in two other species of cats Bateson



found the lower premolar abnormal. In a skull of *F. tigris* "the anterior right lower premolar has a thin supernumerary root on the internal side of the tooth at the level between the two normal roots."

In a skull of *F. fontanieri* the right lower premolar "has an additional talon on the internal and anterior surface."



ABNORMAL POSITION OF SECOND  
LOWER PREMOLAR.

**Number.** I have never noted the absence of this tooth or a case of a supernumerary lower premolar. Hensel records an additional tooth in front of the premolar and behind the canine in four cases out of two hundred and fifty-two skulls,—once on both sides of the lower jaw, the abnormal tooth being as large as the normal, once on the right side, and once on the left.



**Second Lower Premolar** ( $\frac{—}{pm\ 2}$ ).—The only abnormality observed in this tooth is its occasional oblique insertion in the jaw (Fig. 363).

**Lower Molar** ( $\frac{—}{m}$ ).—**Size.** The lower sectorial varies in size as the upper sectorial varies. In only one specimen of very many studied was there evidence of an additional fang. This was shown in the presence of a small alveolus in the interval between the two normal alveoli, but on the outer side of the jaw (right). This is not an uncommon variation in the lower milk sectorial (Fig. 364).

FIG. 364.



ABNORMAL LOWER MILK MOLARS.

**Number.** I have no record of the absence of the lower sectorial. Supernumerary lower molars are occasionally seen. Hensel notes two such cases: in one the additional tooth was a small one placed internal to the middle of the lower sectorial and divided into two cusps, hence it was a copy of the normal tooth; in the other case the abnormal tooth was placed internal to the lower end of the sectorial, but it was not so distinctly divided into two cusps. Wyman<sup>1</sup> gives a case of “supernumerary permanent molar in the lower jaw.” No cases of additional lower molars of a tubercular kind like the small upper molar have been recorded as occurring in the cat, although Hensel, Bateson, Schlegel,<sup>2</sup> and Magitot<sup>3</sup> have seen them in other of the Felidæ.

### HUMAN TEETH.

Man has normally thirty-two teeth, comprising on each side, above and below, two incisors, one canine, two premolars, and three molars. The dental formula therefore is  $i\ \frac{2}{2}, c\ \frac{1}{1}, pm\ \frac{2}{2}, m\ \frac{3}{3} = 32$ . The canines are sometimes called the cuspids, the eye teeth, and the stomach

<sup>1</sup> Proc. Boston N. H. S., v. p. 160.

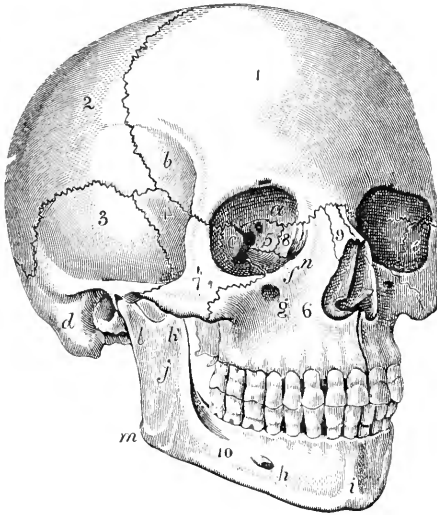
<sup>2</sup> Proc. Zool. Soc., 1866, p. 419.

<sup>3</sup> Anom. Syst. Dent., p. 103.

teeth; the premolars are very generally known as the bicuspid; and the third molars, because of their late appearance, are the wisdom teeth.

The human dentition differs in many ways from the typical carnivorous dentition of the cat. The teeth are planted in the jaws

FIG. 365.



THE SKULL, SEEN PARTLY IN FRONT AND ON THE RIGHT SIDE.

1, frontal bone; 2, parietal bone; 3, temporal bone, squamous portion; 4, sphenoid bone, temporal surface of its great wing; 5, ethmoid bone, orbital surface; 6, maxilla; 7, malar bone; 8, lachrymal bone; 9, nasal bone; 10, mandible; *a*, orbital plate of the frontal bone; *b*, temporal surface; *c*, orbital surface of the large wing of the sphenoid bone; *d*, mastoid portion of the temporal bone; *e*, orbital surface of the malar bone; *f*, orbital plate of the maxillary; *g*, infraorbital foramen; *h*, mental foramen; *i*, symphysis; *j*, ramus; *k*, coronoid process; *l*, condyloid process; *m*, angle; *n*, lachrymal fossa.

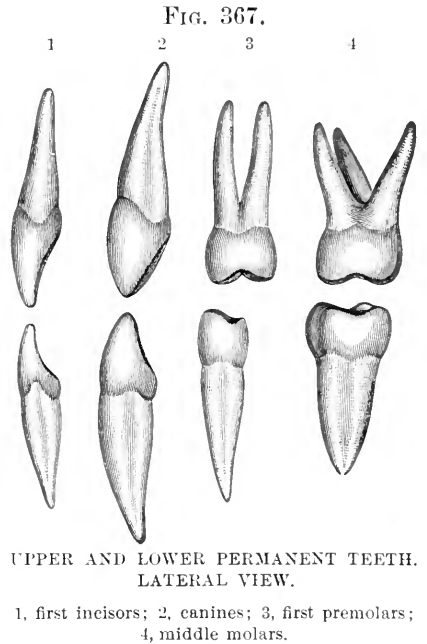
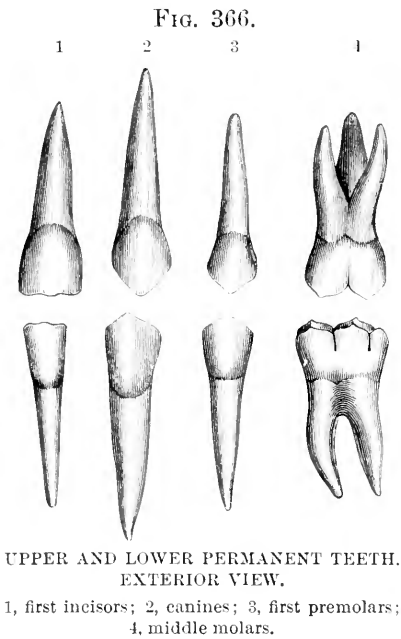
continuously without diastemata (Fig. 365), close together, with their crowns in contact, though their basal portions near the gum are separated by slight intervals. The alveolar borders describe regular parabolic curves; the curve of the upper jaw is slightly larger than that of the under jaw, hence the upper incisors overlap the under incisors and parts of the lower canines; but the grinding surfaces of the other teeth strike together, the under teeth not shearing within the upper, as in the cat's jaw. The upper and lower teeth alternate in such manner that the point of the upper canine comes between the lower canine and the first premolar, the first upper premolar between the two lower

premolars; the alternation then decreases until the last upper molar alone strikes the last lower molar.

The upper back teeth are vertical, but inclined slightly outward; the upper front teeth project forward to a varying degree, in some specimens so slightly that they do not overlap the lower teeth. The lower teeth are vertical, the molars inclining slightly inward. All the teeth of one jaw are of about equal length; none protrude much farther from the gums than the others; hence the masticating line is nearly level.

The number of the human teeth is variable because some of the third molars, or wisdom teeth, frequently are absent, and sometimes the upper lateral incisors fail to develop.

Of the upper incisors (Figs. 366, 367) the medial pair are the larger, and are slightly in advance of the lateral pair. The crown is compressed from before backward and presents a sharp transverse cutting edge, which before the tooth is worn has three small cusps.



The anterior surface is flattened; the posterior surface is flat or concave and sometimes presents a basal swelling which is connected with the angles of the cutting edge by lateral ridges. The crown joins the single fang without a marked cingulum or a decided neck.

The lateral incisors differ from the medial incisors by their smaller size, by the rounding of the lateral angle of the cutting edge of the crown, and by the greater convexity of the outer surface.

The lower incisors are smaller than the upper, and their fangs are more strongly compressed from side to side. The crowns have no distinct basal swellings on their posterior surfaces. The lateral pair are slightly larger than the medial pair.

The canines (Figs. 366, 367) have pointed crowns and longer fangs. The outer surface of the crown is convex; the inner surface presents a vertical median ridge and two marginal ridges which meet at a basal cingular swelling and limit two concave areas. The side of the cutting edge of the crown near the premolar is the longer.

The crown of the lower canine is more obtuse than that of the

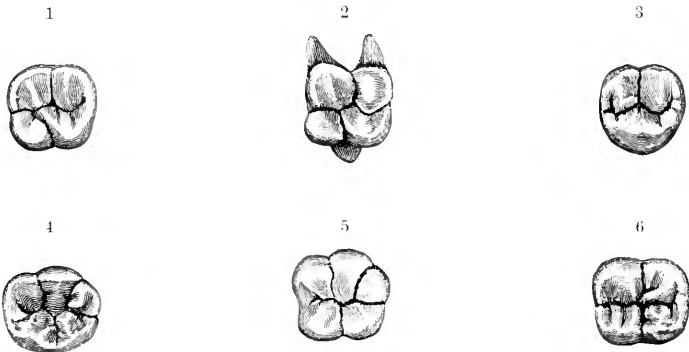
upper canine, and its internal cingular swelling is less marked. The fang is shorter.

The premolars (Figs. 366, 367) differ from the canines by the elevation of the internal basal cingulum into a distinct cusp, or deuterocone; the crowns therefore are bicuspid. The outer cusp is connected with the inner cusp in front and behind by transverse ridges, and separated by an antero-posterior depression which is divided into two pits by the median ridges of the two cusps. The crown is somewhat shorter than the crowns of the canine and of the incisors; the inner and outer surfaces are equally convex. The fang is usually single; sometimes it is double in the second or the first upper premolar.

The upper premolars are compressed from before backward and are transversely wider; the cusps are of nearly equal size. The crowns of the lower premolars are almost circular on cross section, and the inner cusp of the first is generally much smaller than the outer cusp.

The molars (Figs. 366, 367, 368) are the large teeth with cuboidal crowns and one, two, or three fangs. They usually decrease in size

FIG. 368.



TRITURATING SURFACE OF MOLAR TEETH.

1, first upper molar, right side; 2, view of another specimen; 3, second upper molar, right side; 4, first lower molar, right side; 5, view of another specimen; 6, second lower molar, right side.

from before backward, but are variable in size, especially the last or wisdom tooth, which is frequently rudimentary or even absent.

The lower molars, combined, strike against all the upper molars and half of the second upper premolar.

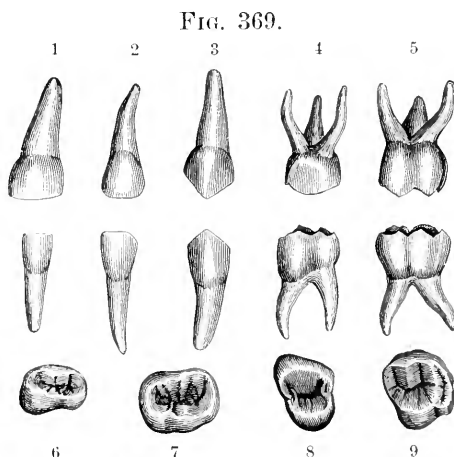
In the lower molars the crown has a greater antero-posterior diameter and presents on its triturating surface five cusps, two on the outer side, two on the inner side, and one behind, formed by the bifurcation of the antero-posterior valley. The last lower molar usually

lacks this fifth cusp. The first two lower molars have two fangs, but in the third the two fangs are more or less coalesced.

The upper molars have the crowns more regularly cuboidal, and elevated into four cusps, one at each angle. The third molar often presents only three cusps, as does sometimes the second molar also, through the failure of the posterior-internal to develop. When there are four cusps the anterior-internal is the largest and curves outward in front and behind to join the external cusps, while the posterior-external cusp curves inward to join the posterior-internal. The elevated part of the triturating surface of the quadritubercular crown is therefore S-shaped, beginning on the outside with the anterior-external cusp and winding inward, then outward, and then inward again to end with the posterior-internal cusp.

The upper molars normally have three fangs, two external and vertical, and one internal larger and directed upward and inward. The last upper molar, however, often has only a single fang.

The deciduous teeth (Fig. 369) number twenty, distributed as follows:  $di \frac{2}{2}$ ,  $dc \frac{1}{1}$ ,  $dm \frac{2}{2}$ . The incisors and canines resemble the permanent teeth, but are relatively broader, with fangs not laterally



THE TEMPORARY TEETH OF ONE SIDE.

1, 2, upper and lower incisors; 3, upper and lower canine; 4, 5, upper and lower molars; 6, 7, triturating surface of the lower molars; 8, 9, triturating surface of the upper molars.

compressed. The molars are formed on the same general pattern as the permanent molars; their crowns are shorter, however, and their fangs more divergent. The crown of the first upper molar sometimes resembles the crown of a premolar.

The deciduous teeth normally begin to appear between the sixth and ninth months, and are all in place by the end of the second year. They erupt in the following order: the medial incisors, the lateral incisors, the first molars, the canines, and the second molars. As a rule, the lower teeth appear before the corresponding upper teeth.

The permanent teeth appear as follows: the first molars at six years, the medial incisors at seven years, the lateral incisors at eight years, the first premolars at nine years, the second premolars at ten years, the canines at twelve years, the second molars at from twelve to fifteen years, and the third molars at from seventeen to twenty-five years.

#### EVOLUTION OF MAMMALIAN TEETH.

We have now studied two distinct types of mammalian dentition,—namely, the **secondont**,<sup>1</sup> that of the cat, in which the crowns of the cheek teeth are pointed and sharp for cutting, and the **bunodont**,<sup>2</sup> that of man, in which the crowns of the cheek teeth are flattened and tubercular for crushing. Other mammals, however, exhibit various forms of tooth structure, according to the nature of the food, the method of articulation of the lower jaw with the skull, and the development and points of attachment of the muscles of mastication. These various forms result principally from modifications in the number and shape of the cusps. A few mammals have no teeth; in a few others every tooth consists of a single cusp; from which primitive condition every stage of advancement can be observed up to the type in which some, at least, of the teeth are crowned by six tubercles. Moreover, the tubercles on the crown may be united in various ways by high crests, often V-shaped and crescentic, or the entire crown may be divided crosswise into a number of distinct parts. In the most complicated forms of teeth the enamel appears to be thrown into folds, vertical, transverse, or oblique, and when these wear through and expose the dentine, many intricate patterns are produced on the surface of the crown.

When the crown of a tubercular tooth is low, the neck above the gum, and the fangs large, the tooth is said to be of the **brachydont**<sup>3</sup> type; when, however, the crown is so high that the cusps appear to be

<sup>1</sup> From *seco*, to cut, and *odous* (Gr.), a tooth.

<sup>2</sup> From (Gr.) *bounos*, a hill, and *odous*.

<sup>3</sup> From (Gr.) *brachys*, short, and *odous*.

drawn out into columns, while the neck is deep in the socket, and the fangs small, the tooth belongs to the **hypsodont**<sup>1</sup> type.

Every group of mammals is characterized by a special kind of dentition; hence the teeth are used as a means of classification, especially since from their hard and resistant qualities they are those parts of extinct animals which are most likely to be preserved in fossil form. It is by these fossil forms that the naturalist is able to trace the descent of existing animals, and their present relations to one another; some mammals which appear to be widely separated in any system of classification based only on the living forms are linked together by a long chain of fossil species so gradually that at no one point can they be said to be distinct. The study of the evolution of the different groups of existing animals is therefore largely dependent upon a study of the evolution of the different forms of teeth. We may pursue this study by at least three different methods:

(1) By comparing the fossil with the existing forms and tracing the development, through long periods of time, of cusp after cusp, noting their gradual change, or differentiation, in various directions, from the simple to the complex type.

(2) By investigating the complete embryological development of the teeth of one species at a time, in order to trace the order of appearance and the relative importance of the different cusps, and thereby learn to what more simple types the finished form is related, or through what grades it has passed to reach its present apparently permanent structure.

(3) By examining the adult dentition of very many individuals of one species and observing all the variations of each tooth in order to learn their meanings,—namely, whether they represent reversions to a more simple stage of development through which the animal has passed, or are the result of mechanical causes still operating to produce change in tooth structure.

All three methods of study should be employed in the solution of the problem; the results gained by one alone of them must necessarily be incomplete; the facts discovered by all of them must, of course, within certain limits agree.

Many investigations have been made in the evolution of tooth forms through palæontological and embryological study, but compara-

<sup>1</sup> From (Gr.) *hypsos*, height, and *odous*.

tively few through the study of variations. For this reason I venture to depart from my rule of avoiding in this volume all theoretical questions, and call attention to some of the possible explanations of the variations which I have observed during the examination of the cheek teeth of many hundred skulls of the domestic cat.

We must first consider some of the theories of the evolution of teeth, especially those based principally upon the study of the teeth of fossil mammals. These theories have been formulated by Ryder,<sup>1</sup> Cope,<sup>2</sup> Allen,<sup>3</sup> Osborn,<sup>4</sup> and Scott,<sup>5</sup> whose publications the student should consult for a full discussion of the subject. The following summary is taken from Professor Cope's last book :

"The distinction of teeth into incisors, canines, and molars appears independently at various points in the line of Vertebrata. Incisors and molars are distinguished in sparoid fishes and in placodont and diactetid reptiles. Canine-like teeth, or pseudo-canines, appear in clepsydroid and crocodilian reptiles and in saurodont fishes. Canine-like incisors appear in the Clepsydroididæ. The variety of character in these structures presented by the Mammalia to be considered is great, and the principles deduced from observation of them are applicable to the Vertebrata in general.

"As mechanical causes of the origin of dental modifications, I have enumerated the following :

"1. Increase of size of a tooth, or a part of a tooth, is due to increased use, within a certain maximum of capacity for increased nutrition.

"2. The change of direction and use of a tooth take place away from the direction of greatest and in the direction of least resistance.

"3. It follows, from their greater flexibility, that crests of crowns of teeth yield to strains more readily than do the cusps.

"4. The increase in the length of crests and cusps in all directions, and therefore the plications of the same, is directly as the irritation from use to which their apices and edges are subjected, to the

<sup>1</sup> Proc. Phila. Acad. Nat. Sci., 1878, p. 45.

<sup>2</sup> The Origin of the Fittest, New York, 1887; The Mechanical Causes of the Development of the Hard Parts of the Mammalia, Jour. Morph., vol. iii., 1889, pp. 137-290; Primary Factors of Organic Evolution, Chicago, 1896.

<sup>3</sup> Dental Cosmos, 1888.

<sup>4</sup> American Naturalist, Dec., 1888, p. 1067.

<sup>5</sup> Proc. Phila. Acad. Nat. Sci., 1892, p. 405.



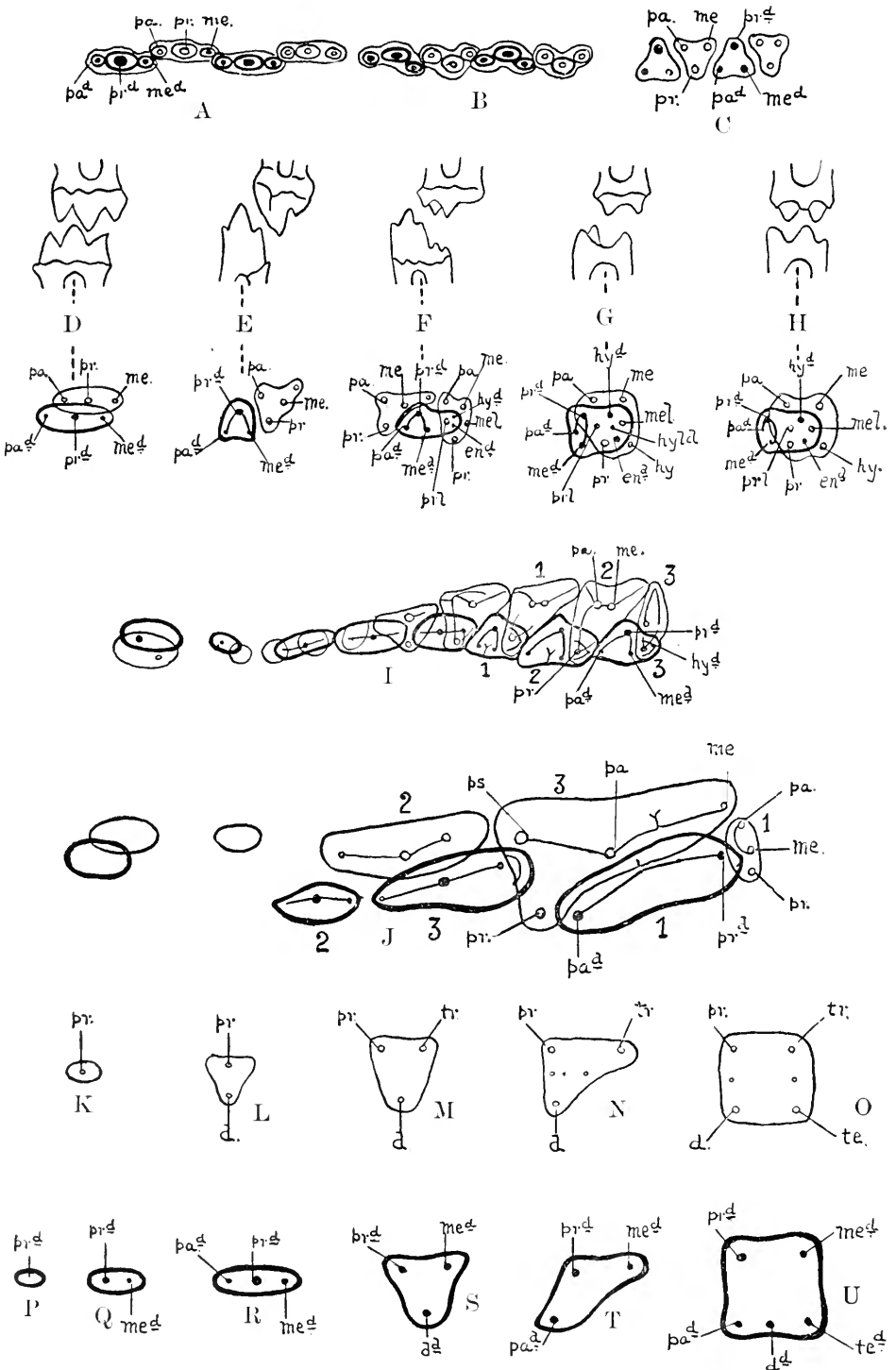
limit set by the destructive effects of such use, or by the recuperative energy of nutrition.

“5. The direction of growth of the branches of a V, or of the horns of a crescent, will be the direction of movement of the corresponding parts of the opposite jaw.”

“**The Origin of Canine Teeth.**—The origin of canine, pseudo-canine, and canine-like incisor teeth is due to the strains sustained by them on account of their position in the jaws at points which are naturally utilized in the seizing of prey or the fighting of enemies. In some reptiles (*Dimetrodon*) the end of the muzzle has been utilized; in crocodiles, the side of the jaw; while the intermediate position has been most used by *Mammalia*. The reason why the canine instead of the incisor teeth have been selected by carnivorous *Mammalia* for prehensile purposes is not at present clear to me. In accordance with Rule I., its increased size has been due to the especial and energetic strains to which it has been subjected while in use as a prehensile or offensive weapon, when buried in the body of its prey or enemy. The superior canine would acquire larger size earlier in time than the inferior canine, since it bears the greater part of such strain, as attached to the more fixed head and body of its possessor. The anterior teeth of the lower jaw would be less available for use, since they offer weaker and less fixed resistance to the opposing body. That the first tooth behind the canine was not generally enlarged is (under I.) due to the fact that its posterior position prevents it from having the same amount of use, and experiencing the strain that a tooth more anteriorly placed necessarily receives. It is excluded from considerable use by the projecting muzzle above and in front of it. That it was not drawn out into a horizontal position was due to the presence of teeth anterior to it.”

**Development of Molar Teeth.**—“In fishes and reptiles, where teeth occasionally present very primitive conditions, the theory of the origin of particular types of molar teeth is more simple than in the case of *Mammalia*. The observations of Hütter on the action of osteoblasts under stimulus show that under moderate irritation osseous tissue is deposited, while under severe pressure osseous tissue is removed. Kölliker has shown that the action of these bodies is the same in dentine as in true bone. Hence modifications of dental structure must stand in close relation to the uses to which they are

FIG. 370.



DIAGRAMS ILLUSTRATING THE EVOLUTION OF THE CROWNS OF THE PREMOLAR AND MOLAR TEETH IN MAMMALS.

The lower teeth are represented by heavy outlines, the upper teeth by light outlines; the outer side of each tooth is supposed to face toward the top of the page, and the anterior side to the left.

The references on the upper teeth are: *pr*, protocone; *pa*, paracone; *me*, metacone; *hy*, hypocone; *prl*, protoconule; *mel*, metaconule; *tr*, tritoecone; *d*, deuterocone; *te*, tertiocone; *ps*, protostyle. On the lower teeth, *pr<sup>d</sup>*, protoconid; *pa<sup>d</sup>*, paraconid; *me<sup>d</sup>*, metaconid; *hy<sup>d</sup>*, hypoconid; *en<sup>d</sup>*, entocoid; *hyl<sup>d</sup>*, hypoconulid; *d<sup>d</sup>*, deuterocoid; *te<sup>d</sup>*, tertiocoid.

A-C, horizontal section of tricuspidate molars of both jaws in mutual relation. A, *Triconodon*; B, *Menacodon*; C, ideal tritubercular molars approached by *Menacodon*, B. (After Cope.)

D-H, successive modifications from the triconodont, D; the double tritubercular, E; the carnivorous tritubercular, F; to the less and more complete quadritubercular, G, H. (From Osborn.) In each stage the upper figure is the lateral view of the teeth and the lower figure is the diagram of the apposition of the surfaces of the crowns. The genera represented are: *Triconodon*, D; *Peralestes* and *Spalacotherium*, E; *Didymictis*, F; *Microclonus*, G; *Hypsoodus*, H.

I, the apposition of the inferior and superior molars of *Stypolophus Whitii* (Cope), one of the *Crocodynta*, the ancestors of the *Carnivora*. (After Cope.) Only the true molars are numbered.

J, the apposition of the cheek teeth of the Cat; premolars and molars numbered.

K-V, evolution of the premolars from the haplodont to the quadritubercular type, according to Scott; K-O, upper premolars; P-V, lower premolars.

put. Thus severe pressure on a simple tooth crown would, if long continued, cause it to expand laterally, or in the direction of least resistance, and to grow but little in its vertical axis, *i.e.*, in the direction of greatest resistance. The molar teeth have been subjected to much more severe direct irritation from use than any others in the jaws, and this will account for their increased diameters. In the case of the eutherian Mammalia, molar teeth are not traceable back to ancestral types of reptilian molars, but to simple conic (haplodont) reptilian teeth."

"The greater number of types of mammals have derived the character of their molar teeth from the stages of the following succession :

"(1.) A simple cone or reptilian crown, alternating with that of the other jaw (haplodont type)." In the upper jaw the cone is termed a protocone, in the lower jaw a protoconid.

(2.) To the simple cone are first added three or four small denticles along the edges; these are then replaced by an anterior and a posterior cusp (Fig. 370, A), in the upper jaw termed paracone and metacone, and in the lower jaw paraconid and metaconid respectively. Thus is produced the triconodont type, exhibited by the Triconodontidae, early Jurassic Mammals. "No mechanical cause can be assigned for the development of these cusps from the denticles, but the nutrition of the parts probably has had an important influence on the process. Each basal cusplet stands nearer to the point of entrance to the crown of the nutritive artery, which ascends or descends through the root, than any other cusplet, and would therefore grow more rapidly than any other secondary part of the crown under stimulus of use. The basal cusplets have thus replaced those occupying more elevated

positions on the principal cusp, and ultimately in some groups equal it in dimensions; as in the case of the inferior sectorial of Carnivora and in quadritubercular types."

(3.) The secondary cusps of the triconodont molars, the paracones, metacones, paraconids, and metaconids, "serve to fill up the spaces between the alternating principal cusps, the protocones and protoconids, hence a certain amount of interference results.

"As the lesser cusps are the least resistant to the wedging pressure of such contact, their position would change under its influence, rather than the large central cusps. The lower jaw fitting within the upper, the effect of the collision between the major cusps of the one jaw and cusplets of the other would be to emphasize the relation still more; that is, the cusplets of the upper jaw would be wedged outward, the major cusps retaining at first their original alternate position (Fig. 370, B). With increase of the size of the teeth the cusps would soon assume in each jaw a position more or less transverse to that of the other jaw, producing as a result of the crowding a crown with a triangular section in both." In other words, in the upper tooth the protocone begins to move inward or medially, the paracone and metacone remaining upon the outer side of the crown; while in the lower teeth the protoconid remains upon the outer side of the crown, the paraconid and metaconid shifting to the inner side; hence in the upper tooth the protocone forms the medial angle of the triangular crown or trigon, but in the lower tooth the protoconid forms the outer angle of the triangular crown or trigonid (Fig. 370, C). This type of cheek tooth is termed the tritubercular type.

(4.) In the tritubercular dentition the crowns proper of the teeth of one jaw alternate with those of the other (Fig. 370, E). In the next stage of molar development, to the lower molar is added at first a low cingulum at the posterior base; this gradually develops by use into a broad heel which opposes such parts of the crown of the next upper molar as come in contact with it, and hence to the primitive shearing action between the triangular teeth is added an opposing grinding action, so that each lower molar opposes two upper molars or shears against one and opposes the other (Fig. 370, F). The heel of the lower molar may develop two cusps, whereof the outer is known as the hypoconid and the inner as the entoconid. This type of tooth is known as the tuberculo-sectorial type. From this

stage, as we shall see, the carnivorous and sectorial dentition is derived.

(5.) The upper molar while in the tritubercular stage may develop small cusps in the lines connecting the protocone with the paracone and the metacone. The anterior of these cusps is termed the protoconule, the posterior the metaconule. The great change in the upper molar forming the fifth stage is produced by the addition of a posterior inner cusp or hypocone to the crown, with loss of the anterior inner cusp or paracone. The heel of the lower molar is elevated and sometimes develops a median cusp or hypoconulid. The teeth thus become opposite and quadritubercular (Fig. 370, G, H). From this quadritubercular type almost all the higher mammals may be traced back through successive stages of simplification. "This is the type of the *Quadrumania* and *Insectivora* as well as the inferior true *Ungulates*. The *Hyracoidea* and higher *Ungulates* add various complexities. Thus the tubercles become flattened, then concave, so as to form V's in the section produced by wearing, or they are joined by cross folds forming various patterns. In the *Proboscidea* the latter become multiplied so as to produce cross-crests."

**Evolution of the Sectorial Dentition.**—The inferior sectorial of the cat is derived from the tuberculosectorial type by the gradual loss of the heel and of the metaconid and the enlargement of the paraconid and the protoconid (compare I and J, Fig. 370). The number of lower molars is gradually reduced to one. "The genesis of the superior sectorial tooth has been explained as follows. In consequence of the fact that the lower canine tooth shuts anterior to the superior canine, the result of the enlargement of the diameters of those teeth will be to cause the crowns of the inferior teeth to be drawn from behind forward against those of the superior teeth when the jaw is closed (Fig. 370, I). Thus a shearing motion would result between the anterior external edge of the lower triangle and the posterior internal edge of the superior triangle. Now the characters of the true sectorial teeth consist in the enormous extension of these same edges in a fore-and-aft direction, the inferior shutting inside of the superior. To account for the development of these blades we must understand that the oblique pressure of the front edge of the lower tooth on the hind edge of the superior tooth has been continued for a very long time. We must then observe that the internal tubercle

of the superior triangle has been pushed continually forward and been reduced to a very small size. Why should this occur? Why should not the corresponding tubercles of the inner side of the lower crown have been pushed backward, since action and reaction are equal? The reason is clear: The superior tubercle is on the internal apex of the trigon, and is supported by but one root, while the resistant portion of the inferior crown is the base of the trigonid, and is supported by two, thus offering twice the resistance to the pressure that the superior does. But why should the anterior part of the inferior tooth move forward, even if it be in the direction of least resistance? This is due to the regular increase in size of the teeth themselves, an increase which can be traced from the beginning to the end of the series. And this increase is the usual result of use."

"The excess of the forward pressure of the inferior teeth against the superior over any backward pressure has left the posterior internal cusp of the triangle of the inferior molar (metaconid) without contact or consequent functional use. It has, consequently, gradually disappeared, having become small in the highest Canidæ, and wanting in some Mustelidæ and all Felidæ. The heel of the same tooth has had a similar history. With the diminution in size of the first superior tubercular, with which it comes in opposition in mastication, its functional stimulus also diminished, and it disappeared sometimes a little sooner (Felidæ) and sometimes a little later (Hyænidæ) than that tooth.

"The specialization of one tooth to the exclusion of others as a sectorial appears to be due to the following causes. It is to be observed in the first place that when a carnivore devours a carcass it cuts off masses with its sectorials, using them as shears. In so doing it brings the part to be divided to the angle or canthus of the soft walls of the mouth, which is at the front of the masseter muscle. At this point the greatest amount of force is gained, since the weight is thus brought immediately to the power, which would not be the case were the sectorial situated much in front of the masseter. On the other hand, the sectorial could not be situated farther back, since it would then be inaccessible to a carcass or mass too large to be taken into the mouth.

"The position of the sectorial tooth being thus shown to be dependent on that of the masseter muscle, it remains to ascertain a probable cause for the relation of the latter to the dental series in

modern Carnivora. Why, for instance, were not the last molars modified into sectorial teeth in these animals, as in the extinct *Hyænodon* and various *Creodonta*? The answer obviously is to be found in the development of the prehensile character of the canine teeth. It is probable that the gape of the mouth in the *Hyænodons* was very wide, since the masseter was situated relatively far posteriorly. In such an animal the anterior parts of the jaws with the canines had little prehensile power, as their form and anterior direction also indicate. They doubtless snapped rather than lacerated their enemies. The same habit is seen in the existing dogs, whose long jaws do not permit the lacerating power of the canines of the *Felidæ*, though more effective in this respect than those of the *Hyænodons*. The usefulness of a lever of the third kind depends on the approximation of the power to the weight; that is, in the present case, the more anterior the position of the masseter muscle, the more effective the canine teeth. Hence it appears that the relation of this muscle to the inferior dental series depended originally on the use of the canines as prehensile and lacerating organs, and that its relative insertion has advanced from behind forward in the history of carnivorous types. Thus it is that the only accessible cheek teeth, the fourth above and the fifth below, have become specialized as sectorials, while the fifth, sixth, and seventh have, firstly, remained tubercular, as in the dogs, or, secondly, have been lost, as in hyænas and cats."

The above explanation of the evolution of the molar teeth has been accepted as amply justified by palæontological evidence. Professor Scott, however, gives a different history for the premolars, which it is necessary for us to consider. To the following extracts from Professor Scott's paper<sup>1</sup> I have added the diagrams K, L, M, N, O, P, Q, R, S, T, U, in Fig. 370:

"The premolars do not display quite the same degree of constancy in the order of succession of their component cusps as do the molars. For this reason the fourth superior premolar [corresponding to the third of the cat] will be taken as the standard. The primitive form of the premolar is a simple cone, implanted by a single fang, which is still preserved in several existing genera and which obviously corresponds to the protocone of the molars (Fig. 370, K). As early as the *Puerco*, however, we find that  $\frac{p}{4}$  in every known genus is com-

<sup>1</sup> Proc. Phila. Acad. Nat. Sci., 1892, pp. 405-444.

plicated by the addition of a second cusp upon the inner or lingual side of the protocone, which may be called the deuterococone (Fig. 370, L). This bicuspid tooth represents a pattern from which all the premolar types of the higher mammalia may be simply and naturally derived by the continued addition of new parts, which in many groups reach the same or an even greater degree of complication than the true molars. Furthermore, this tooth brings out clearly the important fact that, while in the molar the protocone has shifted to the internal or lingual side of the crown, in the premolar it remains upon the external or buccal side of the crown, just as in the inferior molars. From this it follows that the deuterococone has no exact homologue in the molar crown, though functionally and in position it corresponds to the protocone of the molars and in the finished molariform premolar it occupies the antero-internal angle of the crown (Fig. 370, O).

“In the molars the new complications very generally make their first appearance upon the first of the series and then successively upon the second and third, and so in the premolars  $P^4$  is the first to assume new features, and these then advance to the anterior premolars, the first never reaching the full molar pattern, even when the others have exceeded the molars in degree of complexity.

“The second stage of premolar development consists in the addition of a second external cusp, posterior to the protocone, called the tritococone, and which corresponds to the metacone of the molar crown (postero-external cusp, Fig. 370, E), but it cannot be regarded as homologous with that element, because its position with reference to the protocone is entirely different. This stage of development imitates very closely the trigonodont molar, and very frequently this type of premolar displays the intermediate conules either anterior or posterior or both (Fig. 370, N). In position these conules correspond to the protoconule and metaconule of the molars, but are obviously not homologous with them. How very gradually this addition of the tritococone may be effected is beautifully shown in the series formed by placing together the different varieties and species of *Protogonia* and *Phenacodus*. Here the tritococone may be seen in all stages from a minute and scarcely visible cusp, and gradually enlarging until it reaches the size of the protocone (*Phenacodus*).

“This trigonodont stage of the fourth upper premolar is very



widely distributed in the middle and upper eocene, occurring in nearly all perissodactyls and creodonts. With some special modifications it persists to the present time in the sectorial of the Carnivora, in many Insectivora, and in some forms of Artiodactyla (*e.g.*, Dicotyles).

"The final step in the conversion of premolars to the molar pattern is given by the addition of a fourth main element at the postero-internal angle of the crown, the tetartocone, which thus corresponds in position to the hypocone of the molars (Fig. 370, O, H).

"The development of the inferior premolars appears to be somewhat less regular and constant than that of the superior. As in the upper jaw, the complication begins with  $\frac{p}{4}$  and advances anteriorly, but it is worthy of notice that in many forms the complication of the inferior molars begins earlier and proceeds farther than in the case of the upper teeth. As before, the initial point must be taken as a simple conical cusp, the protoconid (Fig. 370, P). Most of the existing ungulates, as well as some recent and many extinct ungulates, retain more or fewer teeth which depart but little from this type. In many forms the only addition to the protoconid consists in a small posterior basal cusp, which the analogy of such Mesozoic mammals as *Amphilestes* and *Triconodon* justifies us in regarding as the equivalent of the metaconid of the molars (Fig. 370, Q). Frequently also an anterior basal cusp, strictly comparable to the paraconid of the molars, is added (Fig. 370, R), and a stage like that of the *Triconodon* molar is attained, consisting of elements which there is every reason to regard as homologous with the three primary cusps of the molars. There is, however, a great difference as to the regularity with which the paraconid and metaconid are present and in the order of their succession; one or the other of them may never appear at all, and while the metaconid is more frequently present and generally makes its appearance first, yet this is by no means invariably the case. Another difference from the molars consists in the ultimate fate of the metaconid in the molariform premolar, where it becomes either part or the whole of the talon (Fig. 370, T) and always remains on the same antero-posterior line with the protoconid, instead of shifting to the internal or lingual side of the latter. In the premolars, therefore, when a cusp occurs occupying the position taken by the metaconid in the molars, it cannot be regarded as homologous with

that element, but rather with the deuterococone of the upper premolar, and may consequently be called the deuterococonid (Fig. 370, V). The latter element also varies as to the relative time of its appearance; sometimes it is the only element present in addition to the protoconid (*e.g.*, *Pelycodus*, *Chriacus*, *Protogonia*, Fig. 370, S), or it may be developed after either the paraconid or the metaconid, or it may appear last of all, and in very many cases it is altogether absent. Yet when it does appear, its homologies are perfectly obvious. A fifth element is sometimes added to the premolar crown posterior to the protoconid and interior to the metaconid, thus occupying the position held by the entoconid of the molars. Clearly, however, it cannot be homologous with that element; its place with reference to the metaconid is entirely different. Its homologies are rather with the tetartocone of the upper premolar, as will appear when it is remembered that there is not that reversal in the position of the cusps of the inferior premolars compared with the superior ones which obtains between the upper and lower molars, the primary cusp or protocone remaining upon the external side of the crown in both upper and lower premolars.

“The following table will serve to exhibit the correspondences of position (not of homology) between the molar and premolar elements when all are present :

UPPER JAW.		LOWER JAW.	
MOLAR.	PREMOLAR.	MOLAR.	PREMOLAR.
Protocone = Deuterocone.		Protoconid = Protoconid.	
Paracone = Protocone.		Paraconid = Paraconid.	
Metacone = Tritocone.		Metaconid = Deuteroconid.	
Hypocone = Tetartocone.		Hypoconid = Metaconid.	
		Entoconid = Tetartoconid. <sup>1</sup>	

Before studying the value of the variations in teeth as evidence of the evolution of tooth-forms, we must put aside abnormalities of structure due to disease or to early disturbances of the tooth germs,

<sup>1</sup> These names for the dental cusps are compounds of *conus*, a cone, and prefixes designating their relative position or relative order of appearance: *protos*, the first; *deuteros*, the second; *tritos*, the third; *tetartos*, the fourth; *para*, beside, alongside; *meta*, behind, after; *hypo*, under; *entos*, within, to the inner side. The suffix *-id* denotes a cusp on a lower tooth.

as well as cases of supernumerary teeth, because the doubling of a tooth appears to be dependent upon some general law manifested in all parts of the body. Inasmuch as we have no record of variations in the incisors and canines, we must confine ourselves to variations in the cheek teeth.

I believe that these variations tend to establish the following points:

(1.) The variations in structure occur almost exclusively in those teeth which are placed in the jaw at the points of greatest functional activity.

(2.) The variations are directly dependent upon use.

(3.) They occasionally occur as reversions to a less specialized type.

(4.) The reduction in the number of teeth begins at the ends of the series; that is, in the regions of the jaw which are functionally less important.

(5.) The evolution of the third upper premolar has taken place in the manner described by Scott, by the addition of an inner cusp or deutercone to the specialized protocone and tritcone.

(6.) The lower molar is developed, as Cope has pointed out, from the tuberculo-sectorial type by the loss of the metaconid and the heel.

I have observed no case of absence of any of the cheek teeth except of the first upper premolar and the upper molar. That the former tooth is gradually disappearing is evident from its rudimentary condition and from the fact that it was entirely absent in almost twenty per cent. of the maxillaries studied. The molar is functionally of more importance, because it still shears on the lower molar; hence it is less frequently absent.

These two teeth are absent in a group of highly specialized extinct cats, the Machærodonts, illustrated by the Sabre-toothed Tiger, in which the dental formula is reduced to  $i \frac{3}{2}, c \frac{1}{1}, pm \frac{2}{2 \text{ or } 1}, m \frac{0}{1} = 24$  or 26. Here, however, the reduction was associated with an enormous development in size of the upper canines, probably to accommodate the animal to special conditions of life, the removal of which led to its extinction.

It is interesting to note that of all the cheek teeth the second upper premolar is the most variable, and, further, that the variations

are all modifications of one type. It would appear as if the region of the jaw of greatest functional importance were moving forward to a point just anterior to the sectorial teeth. It is possible that these variations in the upper premolar may occur only in short-faced cats and are the result of domestication, which has removed the necessity of the very active use of the canines and hence has reduced the length of the muzzle and the gape of the mouth. That some such influence is at work is shown by the occasional absence of the diastemata on either side of the small first upper premolar. In young kittens the face is relatively much shorter than in adults and the sectorial teeth are relatively further forward, since, as we have seen (page 424), the permanent second premolar replaces the deciduous sectorial.

When the lower teeth close within the upper teeth (Fig. 371) the lower second premolar shears against the upper second premolar (Fig. 383); hence the former exhibits an area of wear on the outer anterior surface of the principal cusp (Fig. 379, x), and the upper premolar exhibits a corresponding area on the posterior inner part of its principal cusp. This grinding away of the surface appears always to begin on the cingulum (Fig. 372, x) at a point marked by a swelling or minute cusplet where the apex of the lower premolar strikes with greatest force; thence it gradually extends downward on the crown (Figs. 374, 375). In many specimens of this tooth the outer surface of the posterior fang is marked by a vertical groove which begins below, just above the point where the lower premolar strikes, and is continued upward to the tip of the fang (Fig. 376). In some specimens this groove is shallow, in others so deep that two coalesced posterior fangs are produced (Fig. 380). The inner cusplet of the cingulum is then more conspicuous. In the next stage of this variation the two posterior fangs are separate (Figs. 377, 378, 381), and the new fang is on the inner side, almost directly over the middle of the tooth and crowned by a very distinct cusp. The middle fang gradually diverges from the posterior fang (Fig. 378) and is directed upward and forward. This divergence I believe to be due to the pressure exerted by the lower tooth, inasmuch as the line of divergence lies in the arc of the circle described by the tip of the lower tooth in the vertical movements of the lower jaw.

The development of the inner cusp, or deuterocone, and the separation of the inner fang are accompanied by a general increase in the

FIG. 371.

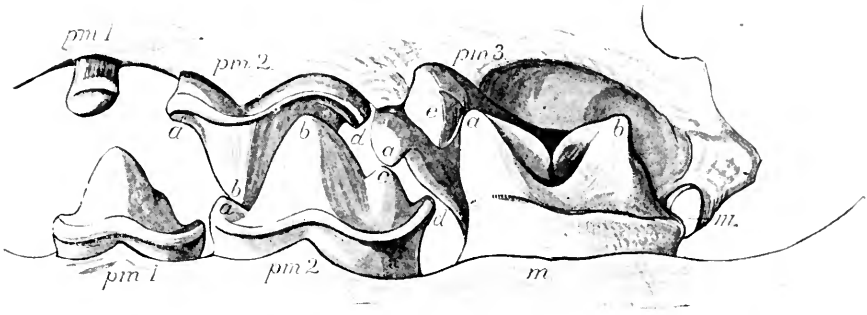


FIG. 372.

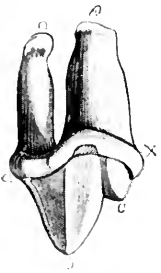


FIG. 373.

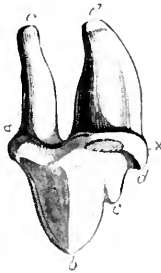


FIG. 374.



FIG. 375.



FIG. 376.



FIG. 377.

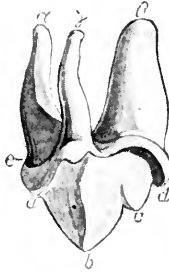


FIG. 378.



FIG. 379.

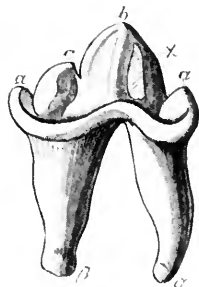


FIG. 380.

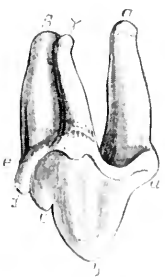


FIG. 381.

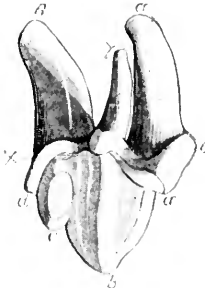


FIG. 382.

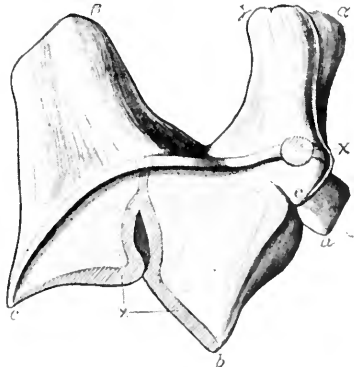


Fig. 371. Relations of the upper and lower cheek teeth. Figs. 372-378, 380, 381. Variations in the second upper premolar. Fig. 379. Second lower premolar. Fig. 382. Upper sectorial. *a*, anterior fang; *b*, posterior fang; *c*, inner fang. *a*, anterior basal cusp; *b*, principal cusp; *c*, posterior basal cusp; *d*, heel; *e*, inner cusp; *x*, areas of wear.

antero-posterior diameter of the tooth and a special increase in the size of the basal cusps.

From this last stage of the variation of the second premolar to the form of the sectorial tooth (Fig. 382) is a short step. I think we are justified in supposing the further process of evolution to have been as follows: continued use has increased the size of the deuterocone, and

pressure (Fig. 383) has moved it forward until it is nearly opposite the anterior basal cusp, or protostyle; the posterior basal cusp, or tritocone, has become longer, and with the principal cusp, or protocone, forms the cutting blade, which is now supported almost entirely by the large posterior fang.

The evolution of the lower molar from the premolar form would be, presumably, a comparatively simple process, requiring merely the lengthening of the posterior basal cusp. We have, however, no evidence from variations which points out this as the method; on the contrary, we have some evidence which is in favor of the view that the lower sectorial is derived from the tuberculo-sectorial molar. This is presented by the occurrence in one specimen of this tooth of an anomalous small posterior outer fang, which was probably crowned

by a small cusp. This structure was doubtless a part of a rudimentary heel, and more especially the outer part bearing the hypoconid. It is not an unusual anomaly in the lower deciduous sectorials (Fig. 364) where the talon and metaconid are well developed, the latter sometimes being placed on the inner side of the crown.

Inferences drawn from variations in the deciduous dentition must be received with caution; we do not yet know the relation existing between the deciduous and permanent dentitions, or even which is primary and which is secondary.

This third cusp on the lower molar might be regarded as the rudimentary protoconid of the original tritubercular stage, the shearing

FIG. 383.

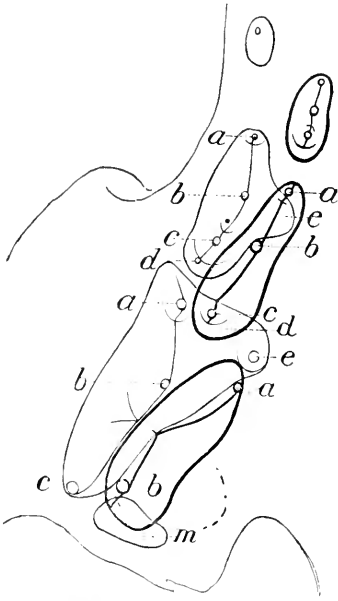


DIAGRAM OF APPPOSITION OF UPPER AND LOWER POSTERIOR TEETH WHEN UPPER SECOND PREMOLAR HAS AN INNER CUSP.

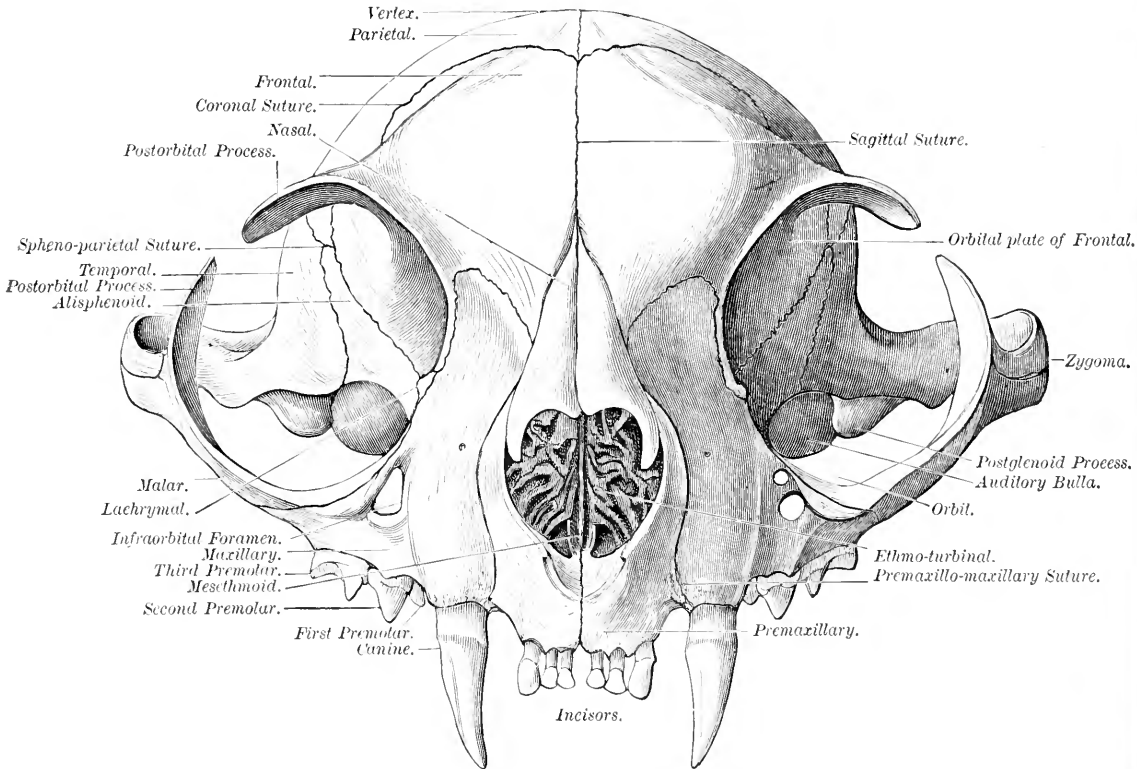
Heavy lines represent lower teeth; light lines, upper teeth: *a*, anterior cusp; *b*, middle cusp; *c*, posterior cusp; *d*, talon; *e*, inner cusp.

blade being formed, not by the paraconid and protoconid, but by the paraconid and metaconid. To this view, however, the palaeontological evidence is clearly opposed. It might be argued that this cusp represents the beginning of a new external cusp arising from the irritation produced on the outer surface by the small upper tubercular molar, and, further, that the tritubercular type of molar was in this way developed from the simple haplodont type, by the addition to a primitive single cusp in the position of the paraconid or metaconid of an external cusp in the position of the protoconid. There is no evidence to support this theory, and it cannot be supposed that the upper molar now so greatly reduced in size could produce so marked an effect upon the lower molar.

## CHAPTER VII

## THE ENTIRE SKULL

FIG. 384.



SKULL, FRONT VIEW.

## FRONT ASPECT OF THE SKULL.

THE outline of the skull when seen from the front (Fig. 384) is nearly circular. It is made up of the outlines of the frontal part of the cranial vault, of the postorbital processes, of the zygoma, and of the horizontal rami of the lower jaw.

The bones of the face form the greater part of the front aspect of the skull; of the cranial bones the frontals are seen at the upper part, and portions of the frontals, temporals, sphenoids, and of the mandible appear at the back of the orbits.

On the front of the skull are the openings of four large cavities;



indeed, the face appears to be little more than a bony framework for these openings. At its lower part is the transverse **oral aperture**, the opening of the mouth; above the mouth, in the middle line, is the smaller, nearly circular **nasal aperture**, or opening of the anterior nares; above this, on each side, are the large openings of the orbits.

After the removal of the lower jaw the outline of the front of the skull becomes distinctly greater than a semicircle. If the lower border be held horizontally, the sides are seen to be directed upward and outward to the level of the zygoma; they then curve upward and inward to meet in the middle line above. The area bounded by this outline consists of (1) a wide, arched, superior portion, the region of the **forehead**; (2) a middle, laterally constricted, **nasal portion**, which lies between the orbits, faces upward and forward in front, faces upward, forward, and outward at the sides, and forms the anterior lateral wall of the nasal cavity; and (3) a lower, wider, **oral portion**, which runs out under the orbits, bounds the mouth above, and carries the upper teeth.

The anterior aspect of the skull is divided into two equal and symmetrical parts by a median vertical suture, which begins above as the **metopic suture**, between the frontal bones, is continued to the anterior nares as the **internasal suture**, between the nasals, and ends below the anterior nares as the **interpremaxillary suture**, between the premaxillaries.

In each half of the face the orbit is the most conspicuous feature. Its opening appears to be circular, but this is due to foreshortening, as its plane slopes backward, upward, and outward from a transverse plane vertical to the straight lower border. Above and between the highest parts of the orbital openings is the region of the forehead, which is flattened on top and slopes gently downward at the sides. When the base of the skull is placed on a horizontal plane, owing to the downward anterior pitch of the roof of the cranium, the forehead faces more upward than forward. A swelling on each frontal bone above the orbital opening, made apparent by a groove running close to the orbital rim and parallel to it, is known as the **superciliary ridge**.

Beginning above where the metopic suture ends, and passing downward and slightly outward to the side of the nasal aperture, is seen the suture which joins the outer edge of the nasal bone to the

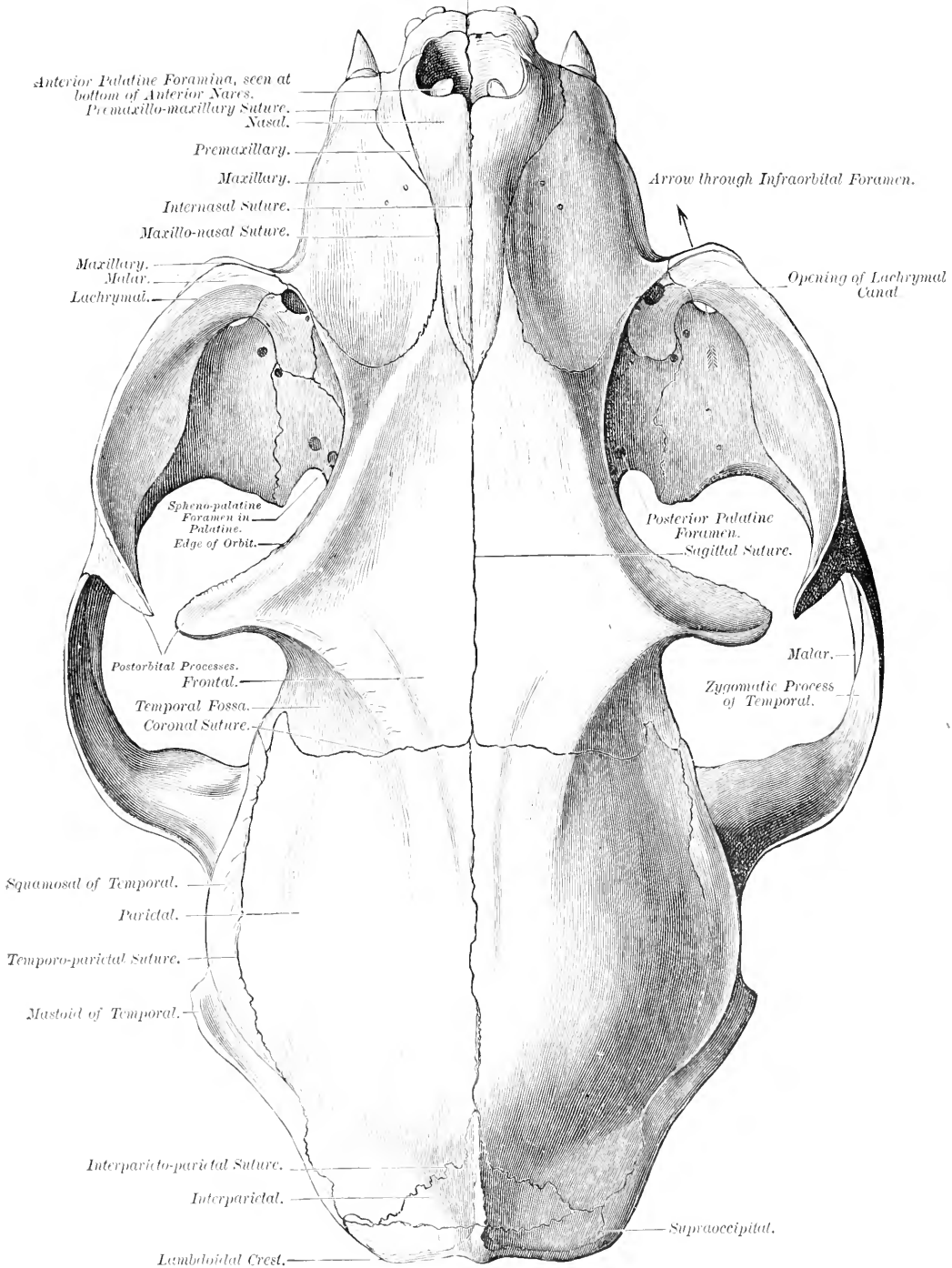
nasal processes of the frontal above, the maxillary in the middle, and the premaxillary below. These parts of the suture are named the **naso-frontal suture**, the **maxillo-nasal suture**, and the **premaxillo-nasal suture** respectively. The nasal bones included between the sutures of the two sides of the face form a high triangular shield for the anterior end of the nasal cavity. At the junction of the naso-frontal and maxillo-nasal sutures, at the tip of the nasal process of the maxillary, the **fronto-maxillary suture** curves upward and outward, then downward and outward, and ends at the external angular process of the frontal bone; it joins the upper arcuate end of the nasal process of the maxillary to the frontal. At the junction of the maxillo-nasal and premaxillo-nasal sutures is the upper end of the **premaxillo-maxillary suture**, which curves downward and outward to end on the lower border just medial to the canine tooth. On the inner maxillary rim of the orbit is the **lachrymal tubercle**. Beneath the orbit, at the inner side, is the **infraorbital foramen**, which transmits the infraorbital nerve and artery. Directly above this foramen on the orbital rim is the inner end of the **malo-maxillary suture**, which, running outward and downward, joins the anterior or malar end of the zygoma to the maxillary bone.

The **nasal aperture**, or opening of the anterior nares, is median and heart-shaped; it is slightly wider than high, and is surrounded by the nasal and premaxillary bones. When the skull is held with the base horizontal, the upper end of the opening is on a level with the lower rim of the orbit. It is separated from the mouth by a narrow strip derived from the premaxillaries. Its lateral outline is encroached upon above by the prominent external angular process of the nasal. On each side below is the small **inferior nasal spine** on the premaxillary. The margins of this opening are sharp above and rounded below; they give attachment to the external cartilages of the nose. In the natural state the anterior end of the median cartilaginous nasal septum converts the nasal aperture into the two equal and symmetrical anterior nares.

#### UPPER ASPECT OF THE SKULL.

The upper aspect of the skull (Fig. 385) presents but few noteworthy features. It may be conveniently studied if the base be placed downward and the posterior end toward the student. The general outline seen from above is oval; its greatest length is two-sevenths

FIG. 385.

*Interpremaxillary Suture.*

THE SKULL, FROM ABOVE.

greater than its greatest width. The surface is convex in both directions, but varies in degree at different points. It presents (1) a median portion which is wide behind and narrow in front; (2) narrow, lateral zygomatic arches which unite laterally the anterior portion, or face, to the posterior portion, or cranium, and bound externally large, irregular openings. In front of the middle of this central portion, on each side, is a pointed projection, the frontal postorbital process, which by joining the postorbital process of the malar converts the large lateral opening bounded externally by the zygoma into an anterior orbital fossa and a posterior temporo-zygomatic fossa. The face occupies the anterior fourth of this view, and has been already studied from in front; the present aspect shows clearly its sloping disposition, inasmuch as its entire surface, with the exception of the small external portion under the orbital rim, is visible.

The superior surface of the cranium is pointed in front, receiving the upper ends of the nasal bones between the frontal nasal processes, on the outer sides whereof lie the upper ends of the maxillaries. The posterior outline is the sharp lambdoidal crest, which is transverse in the middle but slopes forward and downward on each side. At its centre is the external occipital protuberance, more or less prominent, continued forward on the interparietal bone as the sagittal crest. The superior surface of the cranium is flat between the postorbital processes or only slightly convex from before backward and from side to side. In the present position it faces slightly forward as well as upward. Behind the postorbital processes the superior surface is convex from before backward and becomes more and more convex transversely, facing upward, outward, and backward, until the maximum is reached at the transverse line joining the auricular points which are the centres of the external auditory meatuses. Behind this line the superior surface becomes less convex transversely, sloping downward, outward, and forward. The region lying on each side and in front of the lambdoidal crest is concave from before backward. Except at the orbital rims, the superior surface passes downward without a distinct line of demarcation into the lateral surfaces. Curving inward and backward from the upper surface of the postorbital processes are the slightly sinuous temporal ridges, which in well-marked skulls terminate by meeting at the middle line near the posterior end of the parietals. They mark the superior boundary of the area of

attachment of the temporal muscle. The superior surface is divided into two lateral halves by the straight longitudinal **sagittal**<sup>1</sup> suture. At its middle it is crossed by the transverse jagged **fronto-parietal** or **coronal**<sup>2</sup> suture which joins the frontals to the parietals. The anterior half of the sagittal suture, the part which joins the two frontals, is given a distinct name, the **frontal** or **metopic**<sup>3</sup> suture, the term sagittal usually being confined to the remaining portion between the two parietals. At the posterior end of the sagittal suture are the anterior ends of the short **interparieto-parietal** sutures joining the triangular median interparietal to the parietals. These sutures are directed from this point backward, outward, and downward to the point of meeting of the occipito-parietal and interparieto-occipital sutures on each side. The **interparieto-occipital** suture is short and unites the posterior end of the interparietal to the occipital. It runs transversely, parallel and a short distance anterior to the lambdoidal crest, and is continued on each side as the **occipito-parietal** suture. The interparieto-parietal and the occipito-parietal taken together are known as the **lambdoidal suture**. The lambdoidal suture terminates below where it joins the upper ends of two sutures,—namely, the upper part of the temporo-parietal suture, known as the **parieto-mastoid** suture, and the **occipito-mastoid** suture. The superior surface of the skull presents no noteworthy foramina.

Several regions of use in cephalic measurement are best seen in this aspect of the skull. In some skulls close to the jagged posterior end of the sagittal suture on each side is a small foramen in the parietal. The region about this point is known as the **obelion**.<sup>4</sup> A little further below, where the sagittal suture divides into the lambdoidal, is the **lambda**. The external occipital protuberance is known as the **inion**. The point of intersection of the sagittal and coronal sutures is the **bregma**.<sup>5</sup> The point on the coronal suture intersected by the temporal

<sup>1</sup> From *sagitta*, an arrow.

<sup>2</sup> From *corona*, a chaplet, a crown.

<sup>3</sup> From (Gr.) *metopon*, the space between the eyes; the forehead.

<sup>4</sup> From (Gr.) *obelus*, a spit; also a sign ÷ used by ancient writers to mark superfluous passages.

<sup>5</sup> *Bregma* (Gr. from *brecho*, to moisten), the front part of the head, the sinciput. It marks the position in young children of the anterior fontanelle, which is soft and was thought to correspond with the most humid part of the brain.



ridge is the **stephanion**. The junction of the parieto-mastoid, occipito-mastoid, and lambdoidal sutures is known as the **asterion**.<sup>1</sup>

#### LOWER ASPECT OF THE SKULL.

The outline of the lower surface of the skull is an irregular oval, with the long axis longitudinal. The surface, in the main, is flat, but the auditory bullæ behind and the horizontal rami of the lower jaw in front project on each side below the general surface. When the lower jaw is removed the lower surface of the skull proper is visible (Fig. 386). It consists of two well-marked parts, a triangular anterior portion, forming the roof of the mouth, or hard palate, and a quadrilateral posterior portion, forming the base of the cranial cavity. They are joined by a narrow median piece, which supports the soft palate. They are further connected externally on each side by the slender bowed zygomatic arches, which can be best seen on the lateral view, and which are not regarded as parts of the base of the skull, inasmuch as they do not form the lower wall or base of the nasal and cranial cavities. A large square opening is left on either side between the zygomatic arch and the true base of the skull which leads upward into the orbital and zygomatic fossæ. The anterior region lies upon a lower plane than the posterior region. The edges only of the middle connecting region are on the same plane with the anterior region; the region itself is a forward continuation of the posterior region in the form of a wide fossa, which disappears under the middle of the posterior edge of the anterior region, leaving a wide, low opening into the nasal chamber, subdivided in the recent state by the soft parts into two channels known as the **posterior nares**.

The anterior portion, forming the roof of the mouth, is triangular, and is about as long as wide. The anterior angle is truncated and slightly rounded; it carries the six small **incisor teeth**. The slightly elevated lateral margins, or **alveolar borders**, are directed from before backward and outward, and contain the roots of the remaining upper teeth, which are, on each side, the large **canine**, the three **premolars**, and the single **molar**. Intervals, or **diastemata**, exist between the incisors and the canine and anterior and posterior to the small anterior premolar. The posterior end of the lateral border is the **tuberosity** of the maxillary. The outer thirds of the transverse posterior border

<sup>1</sup> From (Gr.) *aster*, a star.

are the anterior edges of the orbital openings. They are straight near the lateral borders, and deeply rounded and emarginate within. The median third forms the lower edge of the posterior nares. In the middle line it is slightly prolonged backward as the **postnasal spine**, which gives attachment to the *azygos uvulæ* muscle. On each side of this middle third the posterior border of the hard palate is continued backward as the edges of the middle pterygoid fossa. The hard palate is formed of the palatine plates of six bones,—the two premaxillaries in front, the two maxillaries in the middle, and the two palatines behind. It is divided into two halves by the median **mesopalatine suture**. The **premaxillo-maxillary sutures** run from the lateral border inward and slightly backward and come together in the middle line at the junction of the anterior and middle thirds. The **transverse palatine suture** is seen a little behind the middle. It runs transversely for a short distance only, and then bends sharply backward and outward, reaching the posterior border on each side not far from its external end. It separates the maxillaries from the palatines. Behind the incisors are several small vascular, incisive foramina, and on each side of the middle line in front are the large, oval **anterior palatine foramina** transmitting the nasal arteries and the nasopalatine nerves. Further back, behind the middle, at some distance from the mesopalatine suture, are the anterior openings of the **posterior palatine canals** for the palatine vessels and nerves.

The hard palate is, in the main, flat, but on each side is a curved, longitudinal ridge, which begins at the posterior end of the anterior palatine foramen, extends backward and slightly outward, and ends, sometimes in a distinct swelling, behind the posterior palatine foramina. In some specimens external to this ridge is a faint groove for the palatine vessels. The thick, tough mucous membrane of the mouth is firmly attached to the entire surface of the hard palate.

The **middle pterygoid fossa** lies between the orbito-zygomatic openings behind the palate and in front of the expanded cranial portion. It occupies the middle fifth of the length and the entire width of the under surface of the skull. Its own length is one-third greater than its width. It is only half as high as wide. From in front it slopes slightly downward and backward; from side to side it is strongly concave. Its anterior wall is limited to the narrow posterior edge of the palatine plate of the palatine, which forms the floor of the pos-



terior nares, through which the fossa communicates directly with the nasal chamber. It is freely open behind. Its sides, formed by the palatines and the pterygoids, are parallel and slope upward and inward from their free, narrow, and rounded lower edges to pass without a distinct break into the roof of the fossa. A well-marked, rounded, longitudinal ridge occupies the centre of the roof and is embraced in front by the diverging posterior ends of the vomer. This ridge is on the under surface of the presphenoidal body and separates the palatines and pterygoids of the two sides. The line of separation is the lower **prespheno-palatine suture** and the **prespheno-ptyergoid suture**, at the junction whereof is seen the transverse **ptyergo-palatine suture**. A small additional piece of the under surface of the presphenoidal body appears also on each side of the median ridge and usually between the palatines. The lower lateral edges terminate behind in the **hamular processes** of the pterygoids, which are directed downward and backward and support the aponeurosis of the tensor palati muscle. Above the roots of these processes the posterior edges of the lateral walls slope upward, backward, and outward and become continuous with the rest of the base of the skull in front of the auditory bullæ. They are hollowed to form the oblong **external ptyergoid fossæ** which afford attachment to the internal ptyergoid muscle. On the outer side of these fossæ are the **external ptyergoid processes**.

Behind the external ptyergoid fossa on each side is a slightly concave area known as the **scaphoid fossa**, from which arise the levator and tensor palati muscles. The scaphoid fossa passes outward and backward over the front end of the auditory bulla into the **Eustachian opening**, which lodges the Eustachian tube and the palatal muscles. On the inner side, and anterior to the scaphoid fossa, at the edge of the ptyergoid bone, is seen the slit-like posterior opening of the **Vidian canal** for the Vidian nerve.

The triangular area lying between the two scaphoid fossæ, contributed by the basisphenoid, passes in front into the middle ptyergoid fossa and behind into the space between the bullæ. It is slightly convex transversely, and affords attachment to the posterior wall of the pharynx. Lateral to the scaphoid fossa is the **foramen ovale**, which transmits the inferior maxillary branch of the trigeminal nerve. In front of this foramen is the **foramen rotundum** for the superior maxil-

lary branch of the trigeminal nerve, beyond which the base of the cranium slopes upward and forward, passing into the posterior wall of the orbital cavity. On the outer side of the foramen ovale the surface is continuous over the lower part of the squamo-sphenoidal suture, with the wide transverse glenoid cavity on the posterior root of the zygomatic arch.

The posterior edge of the glenoid cavity is elevated internally into the postglenoid process, behind which is seen the variable postglenoid venous foramen.

The major portion of the remaining inferior surface of the skull is occupied by the two large auditory bullæ. These prominent, ovoid, bony sacs are situated on each side at the outer posterior part, leaving a flattened oblong space between them. The outline of the bulla is oval, but slightly wider in front than behind. The long axis is contained four times in the total length of the skull, and is a fourth greater than the transverse axis. It is directed from behind obliquely inward and forward. The outer wall of the bulla is pierced for the external auditory meatus, above and exterior to which is seen the narrow under surface of the posterior root of the zygoma. At the anterior end, on the inner side, is the Eustachian opening, on the inner wall of which is the minute opening of the carotid canal, and on the outer side are the Glaserian fissure and the opening of the canal of Huguier. A little behind the middle of the inner margin of the bulla and between it and the basioccipital plate is the small posterior opening of the canal for the rudimentary internal carotid artery. Behind this, again, is the large triangular jugular foramen, at the lower end of the posterior wall whereof is seen the anterior opening of the anterior condyloid foramen. The stylo-hyoid muscle takes origin from the posterior margin of the bulla. Behind the bulla is the transverse lower edge of the paroccipital process, the outer end of which is roughened to afford attachment to the digastric muscle.

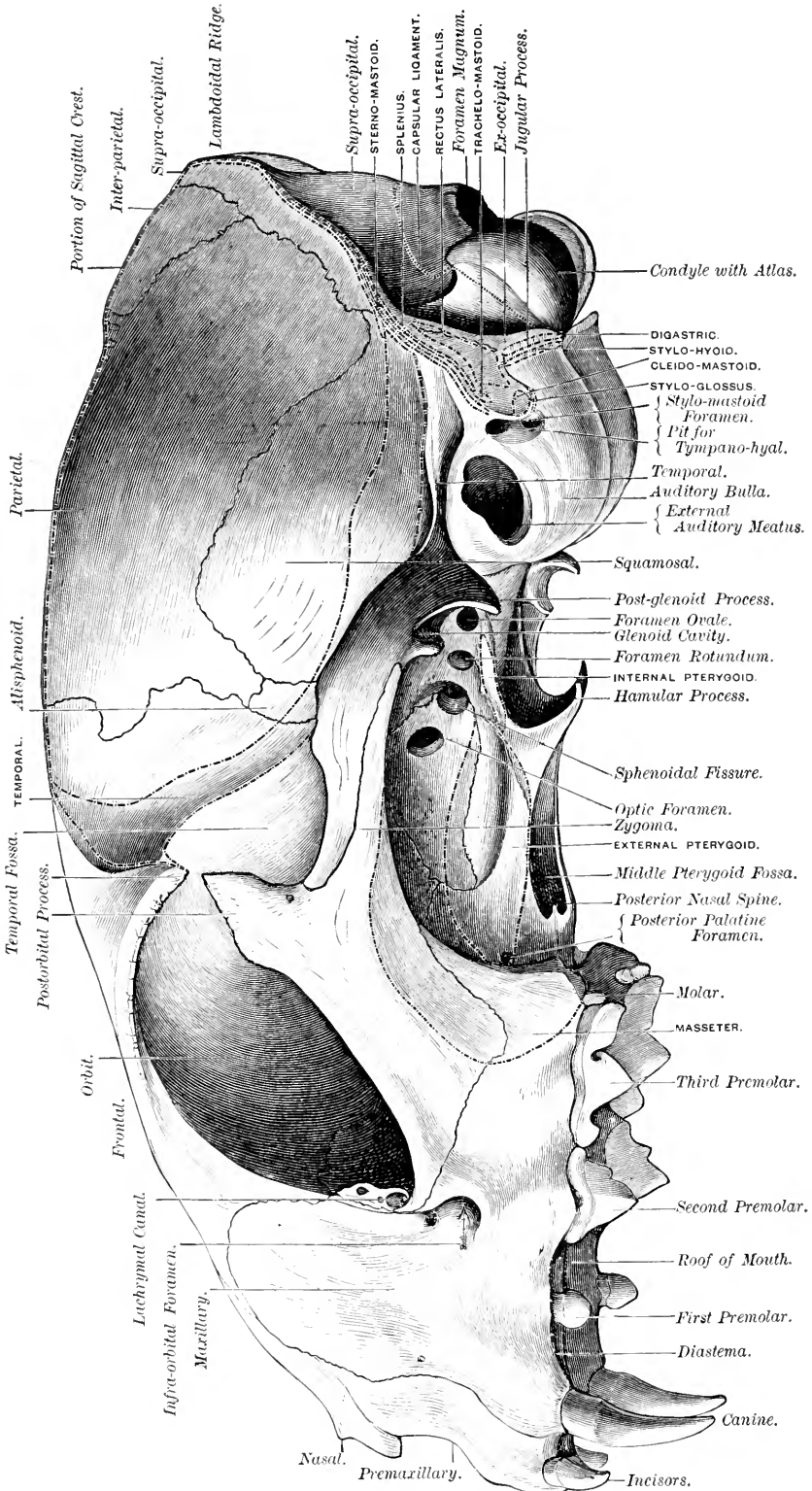
On the outer side of the bulla, behind the auditory meatus and directed downward and forward, is the mastoid process. To its lower edge are attached the stylo-glossus and cleido-mastoid muscles. In front of the mastoid process is the stylo-mastoid foramen, through which the facial nerve gains exit from the skull. Just within the tip of the mastoid process is the pit for the insertion of the tympano-hyal element of the hyoid apparatus.

The space between the two bullæ comprises the middle third of the width of the surface, and is slightly narrower in front than behind. It is twice as long as wide. It is bounded laterally by the inner edges of the bullæ and of the jugular foramina. Behind an imaginary transverse line joining the paroccipital processes, it is expanded on each side into the occipital condyles, between which is the deeply emarginated lower border of the foramen magnum. The anterior point on this border is called the **basion**, and is used as a fixed point in cephalic measurements. The surface between the bullæ is partly on the basisphenoid and partly on the basioccipital, the dividing transverse suture crossing in front of the middle. It is, in general, slightly convex transversely, but on the anterior half or more the median line is depressed, and on each side is inserted the rectus capitis anticus major muscle. The posterior half or less of this space is prominent in the middle line and excavated on each side into fossæ for the insertion of the rectus capitis anticus minor muscle. When the bulla is removed, its points of attachment to the base of the skull proper are seen; they are—in front, on each side of the Eustachian groove and behind the postglenoid process, and behind, just in front of the stylo-mastoid foramen. The area covered by the bulla is mainly the roof of the tympanum, but the large, crescentic posterior fossa, which faces inward, forward, and upward and is formed by the front surface of the paroccipital process and the inner surface of the mastoid process, receives the rounded posterior end of the bulla.

#### SIDE ASPECT OF THE SKULL.

The lateral surface of the skull (Fig. 387) comprises the lateral surfaces of the face and of the cranium. The under jaw forms the lower part of the face, but for convenience should be removed. It will be also found convenient in studying the lateral surface to hold the skull in such a manner that with the surface toward the student the lower border of the base shall be horizontal and the anterior end point to the left. When thus viewed from the side it is seen to be long and low, the greatest height being only three-eighths of the greatest length. The lower outline appears to be straight, except for the anterior irregularities produced by the teeth, the middle projections of the hamular process, and the posterior swelling marking the lower outline of the bulla. The lower outline as a whole is,

FIG. 387.



THE SKULL: THE LEFT SIDE.

however, slightly emarginate. The upper outline is strongly arcuate, reaching its highest point somewhere between the middle and the posterior end. The posterior outline is short and straight, and is directed from the end of the lower outline backward as well as upward. The upper outline descends so low in front that there is little left which may be called an anterior outline; such, however, may be designated the short line formed by the lateral edge of the nasal aperture. This line has the same general direction as the posterior outline; its upper fourth, formed by the lower end of the nasal bone, projects further forward, beneath which the portion contributed by the premaxillary is emarginate above and straight below. The lateral surface of the skull may be said to be convex in both directions. It is deeply impressed, however, by a large fossa, which is made up of three confluent fossæ: the orbit in front continued behind, above into the temporal fossa, and below into the zygomatic fossa. The large fossa occupies the entire middle three-fifths of the surface and is limited externally by the strong zygomatic arch. In front of the orbit is the region of the upper jaw. This part is L-shaped; the vertical portion, composed of the premaxillary, nasal, and maxillary bones, slopes upward, backward, and inward; it gives attachment to the cartilage of the nose and to a few small muscles. The horizontal portion, lying under the anterior end of the zygoma, slopes outward and slightly forward. The teeth project downward from the lower portion of the upper jaw; under the lowest point of the anterior rim of the orbit is the depression leading into the infraorbital foramen.

The **zygoma** is formed by the malar in front and the zygomatic process of the temporal behind. The **malo-temporal suture**, which unites them, crosses the zygoma obliquely from the root of the post-orbital process above to the glenoid cavity below and behind. The anterior half of the zygoma is higher than the posterior half, and is arched upward, and near the middle sends upward and backward the **postorbital process**, which is connected by fascia with the corresponding process of the frontal. The anterior end of the zygoma is joined with the malar process of the maxillary by the **malo-maxillary suture**. Its posterior end bears on its under surface the large, transverse **glenoid cavity**, and is continued backward on the temporal as a ridge or posterior root. The zygoma is bowed outwardly; on the

anterior or malar part of its outer surface is a curved ridge, to which the masseter muscle is attached. The inner surface is concave, and gives attachment also to the masseter.

Under the posterior root of the zygoma is the auditory bulla, in the outer wall whereof is seen the large external auditory meatus, across which is stretched the drum of the ear, or tympanic membrane. Around the margin of the meatus is attached the cartilaginous external ear. Behind the external auditory meatus is the small stylo-mastoid foramen, and behind this, again, the mastoid process, the outer surface of which faces also backward and appears on the posterior aspect of the skull. Concealed by the tip of the mastoid is the hyoid pit for the attachment of the tympano-hyal.

The strong lambdoidal crest forms the posterior outline of the lateral region, and is continued down the front of the mastoid. It gives attachment to muscles which are directed anteriorly on the skull,—namely, the temporal, the occipito-frontal, and some of the small auricular muscles,—and to others which are directed backward to the trunk,—namely, the cephalo-humeral, the sterno-mastoid, the splenius, and the trachelo-mastoid.

On the side of the skull above the posterior end of the zygoma is the arched squamous or temporo-parietal suture uniting the squamous of the temporal and the parietal bone. It turns behind upward and backward parallel with the lambdoidal crest as the parieto-mastoid suture, ending at the asterion above. The front part of the squamous suture is joined in the temporal fossa to the coronal suture and the fronto-sphenoidal suture by a short longitudinal suture. As this suture separates the parietal from the sphenoid, it is called the spheno-parietal suture. The region marked by this H-shaped arrangement of sutures is known as the pterion.<sup>1</sup> The region of the skull behind the greatest lateral convexity, which is on a vertical line passing through the auditory meatus, becomes gradually concave from before backward, but still remains slightly convex from above downward. The temporal muscle covers almost the entire lateral wall of the cranium, and is attached principally to the lambdoidal crest, along the temporal ridge, and to a narrow strip of the surface lying above the posterior root of the zygoma and curving upward and forward to reach the frontal postorbital process.

<sup>1</sup> From (Gr.) *pteron*, a feather, a wing.

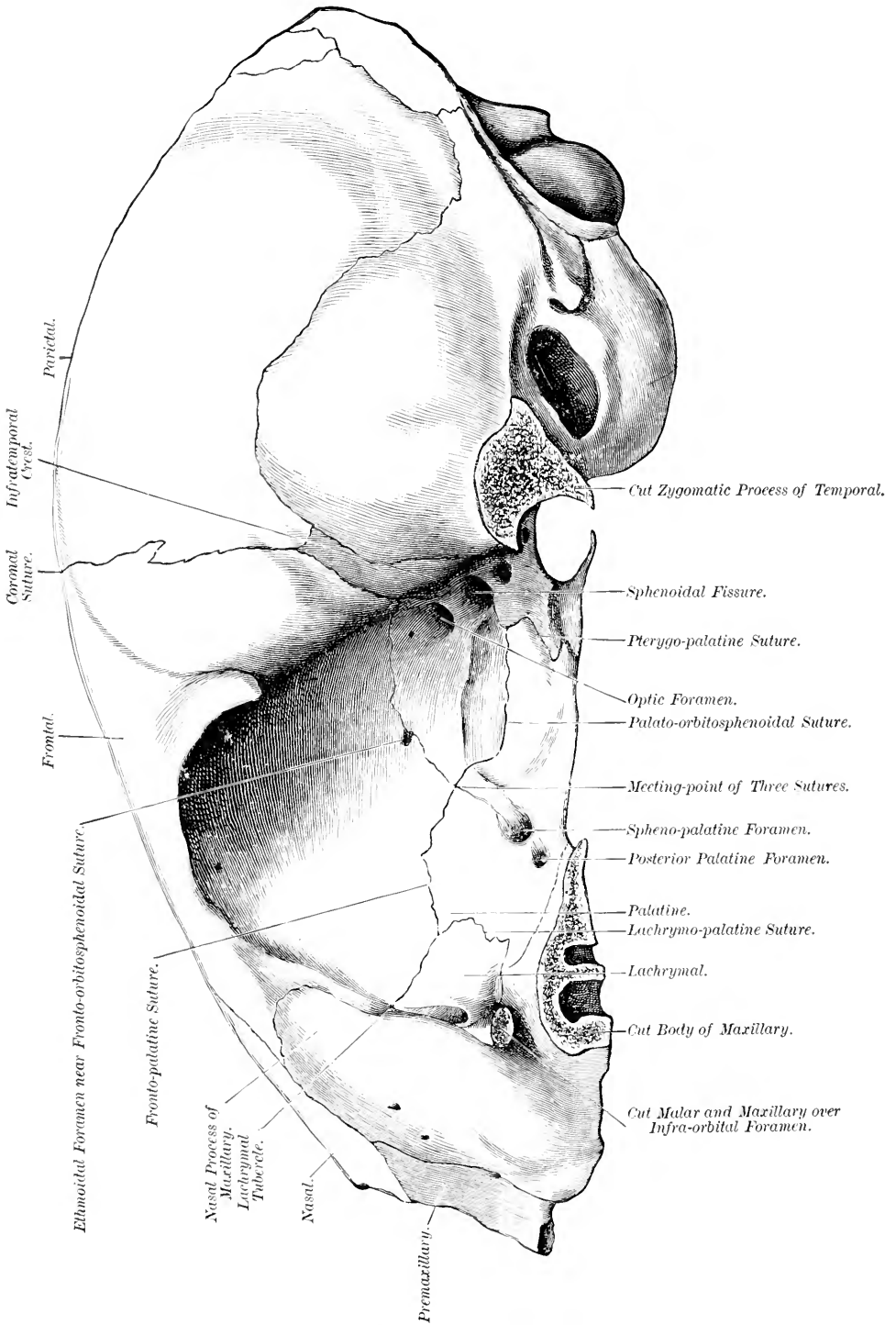
## THE ORBITS.

The Orbits (Figs. 387, 388) lie at the sides of the skull in front under the middle of the cranial cavity and separated from each other by the nasal cavity and by the anterior part of the cranial cavity.

Each orbit is a conical cavity pointing from in front inward, backward, and downward, so that the inner ends of the two if continued into the cranial cavity would meet over the sella turcica. The base of the cone is at the plane of the large anterior opening and limited by the orbital rim; it faces forward, outward, and upward. The apex is at the side of the skull, behind the middle, near the optic foramen, and points backward, inward, and downward. The antero-posterior diameter of the cone is one-fifth greater than the widest diameter of its base in front. At their posterior ends the orbits are separated only by the presphenoid, but at their anterior ends by the greatest width of the nasal cavity.

The **orbital rim** is formed in front by the posterior edge of the nasal process of the maxillary and the upper edge of the malar, the junction of the two lying at the anterior end of the long diameter. It is bounded below by the same edge of the malar, above by the internal angular process, the orbital border, and the postorbital process of the frontal. The opening of the orbit, surrounded by the orbital rim, is oval, and is a fifth wider than high. The wider diameter is not transverse; from within, it points upward as well as outward. The vertical diameter, at right angles to this, is not really vertical, but runs from below inward and upward. The orbits are not wholly enclosed by bony walls, but large openings are left, which are in the natural state, however, filled by muscles and fascia. Of the walls, the **inner wall** alone is complete; the **lower wall**, or **floor**, is limited to the orbital plate of the maxillary in the inner part of the anterior third and to a strip of the palatine along the inner side. The **outer wall** is present only in front, in the form of a bony ring, which is furnished by the malar bone and the frontal postorbital process. The upper wall, or **roof**, is formed by the orbital plate of the frontal and part of the orbital surface of the sphenoid. It is limited on the outside by a line drawn between the root of the frontal postorbital process above and the front of the foramen rotundum below along a marked convexity situated on the frontal and alisphenoid bones. A plane directed from this convexity outward and forward in such a manner as to pass

FIG. 388.



THE SKULL. LEFT SIDE. ZYGOMA AND LOWER JAW REMOVED TO SHOW ORBIT.



through the postorbital process and the tuberosity of the maxillary would form the rest of the outer wall of the orbit and separate it from the zygomatic and temporal fossæ.

The inner wall of the orbit is triangular, high in front, and meeting the upper and lower walls behind. It is almost flat, but curves outward above into the upper wall and below into the lower wall. Its upper two-thirds are contributed by the frontal and the lower third by the lachrymal in front and the palatine and orbitosphenoid behind. The suture between the frontal and these bones is in the main horizontal; it begins at the lachrymal tubercle of the maxillary on the anterior edge, runs backward and downward as the **fronto-lachrymal suture**, then for an equal distance horizontally as the **fronto-palatine suture**, then passes backward and upward as the **fronto-orbitosphenoidal suture**, and ends by meeting that suture which, as a continuation of the coronal suture, separates the frontal from the alisphenoid, then the alisphenoid from the orbitosphenoid, and terminates below at the posterior part of the orbit in the sphenoidal fissure. From the anterior edge of the sphenoidal fissure a straight suture is continued forward, below the pterygoid line on the orbitosphenoid, and at its anterior end turns sharply upward and meets the junction of the fronto-palatine and fronto-orbitosphenoidal sutures. This is the **palato-orbitosphenoidal suture** which separates the orbitosphenoid from the palatine. The only other suture on the inner wall of the orbit is the straight, nearly vertical **lachrymo-palatine suture** between the lachrymal and the palatine. At the anterior edge of the orbit are the **lachrymal tubercle**, the **lachrymal groove**, and the opening of the lachrymal canal. In some specimens behind the lachrymal bone is an irregular area derived from the ethmoid, known as the **os planum**. In the palatine behind and below this area, near the lower edge of the wall, are the large **spheno-palatine foramen** and the small **posterior palatine foramen**, transmitting blood-vessels and nerves to the nose and the roof of the mouth. At the posterior part of the orbit are two large foramina, whereof the upper, anterior, and smaller is the **optic foramen**. It pierces the orbitosphenoid and gives passage to the second cranial or optic nerve and to a meningeal artery; from the surface round its margin spring the muscles of the eyeball. The larger opening behind and below the optic foramen is the **sphenoidal fissure**. It lies between the orbitosphenoid and the alisphenoid, is irregularly

oval, and transmits the oculo-motor, pathetic, and abducens nerves, and the ophthalmic division of the trigeminal nerve, besides blood-vessels supplying the orbit. A slightly arcuate line joining the sphenoidal fissure and the spheno-palatine foramen marks the upper limit of the area of origin of the external pterygoid muscle. Below this line the inner wall of the orbit passes into the lower wall and faces upward and outward. In or above the suture between the orbitosphenoid and the frontal are two small foramina which lead into the olfactory fossa of the cranium or into the nasal cavity. They are the **anterior** and **posterior ethmoidal foramina**, which transmit the ethmoidal vessels and nerves.

The orbital plate of the maxillary forms the anterior part of the floor of the orbit and passes in front through the infraorbital foramen. On the inner wall of this foramen, or just behind it, is the anterior dental foramen. The floor of the orbit itself is perforated by many small **posterior dental foramina** for the nerves and vessels of the upper teeth. At the inner edge of the floor is the straight longitudinal **maxillo-lachrymal suture**, continued as the **maxillo-palatine suture** of the orbit backward and slightly outward to the anterior margin of the bony floor.

#### THE ZYGOMATIC FOSSÆ.

Each Zygomatic Fossa lies behind the orbit and below the temporal fossa, and, in part, also in front of it. It is triangular, narrow within and wide without; it communicates above with the temporal fossa and opens below on the lower surface of the skull. The artificial upper limit of the zygomatic fossa is a plane which passes through the upper edge of the zygoma, the anterior edge of the glenoid cavity, and the infratemporal crest on the alisphenoid, and intersects in front the artificial outer plane of the orbit along a horizontal line. The zygomatic fossa cannot be distinguished from the orbit in front, except artificially by considering as zygomatic all the region behind the imaginary plane described as limiting the orbit externally, and also, from its direction, posteriorly. The zygomatic fossa is limited internally by the alisphenoid and behind by the front of the basal portion of the zygoma. Its outer boundary is the zygomatic arch. On the inner wall of the fossa, just in front of the glenoid cavity, is seen the **squamo-sphenoidal suture** running upward and slightly backward

into the temporal fossa. The zygomatic fossa is filled by the coronoid process of the lower jaw and by the pterygoid muscles.

#### THE TEMPORAL FOSSÆ.

Each Temporal Fossa lies above and behind the zygomatic fossa. Its upper limit is a line known as the **temporal ridge**, which begins at the root of the postorbital process of the frontal, curves upward and inward on the frontal and parietal bones, and fades away near the median line above and behind the middle of the parietal bone. It has no well-defined posterior limit, and may be said to end with the greatest lateral convexity of the skull. The temporal fossa does not extend below the level of the zygoma. It passes into the orbit in front, and is separated externally from it only by the postorbital processes. It is filled by the tip of the coronoid process of the mandible and by the large temporal muscle.

#### POSTERIOR ASPECT OF THE SKULL.

The outline of the skull when viewed from behind is dome-shaped, and does not include the projections caused by the zygomatic processes and the auditory bullæ. Above, and at the sides, the posterior outline is the outline of the greatest transverse convexity of the vault of the cranium, and is produced by the parietals and the temporals. The lower outline is formed by the lower edges of the mastoid portions of the temporals and the vertical plate of the occipital.

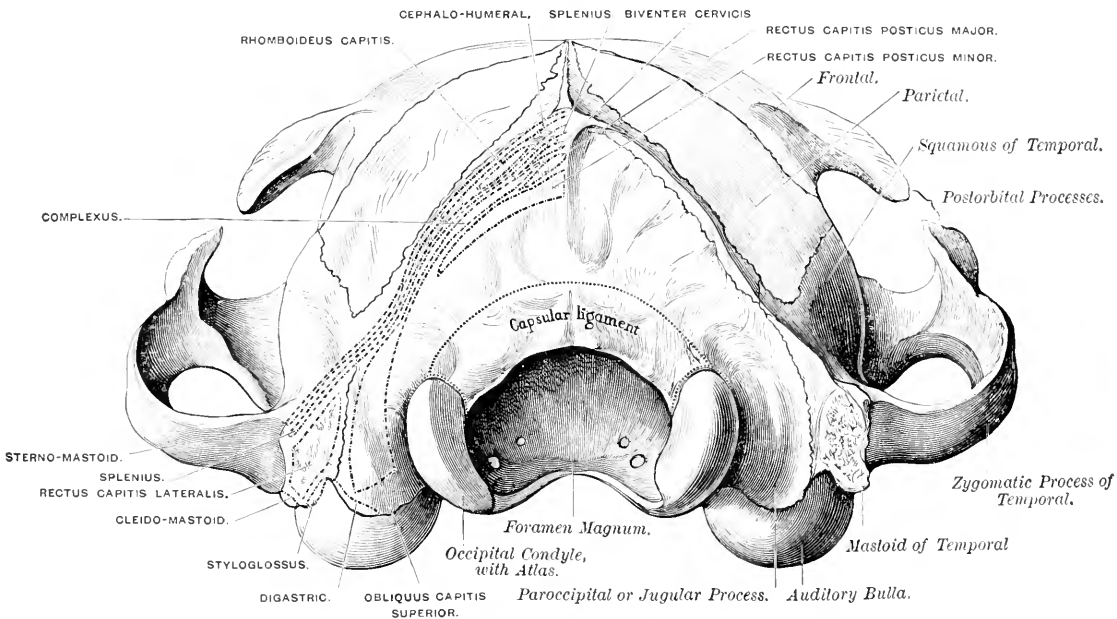
The true posterior surface of the skull fills a part of the outline of the posterior aspect. It is triangular, the base of the triangle identical with the lower outline, except for the swellings produced by the auditory bullæ further forward on the base of the cranium. The apex of the triangle is situated at about the middle of the area, from which point the sides run downward, outward, and forward to the lateral angles and form the **lambdoidal crest**. The region above the lambdoidal crest has already been studied in the consideration of the superior aspect of the skull.

The true posterior surface of the skull is the posterior surface of the vertical plate of the occipital, composed of the supraoccipital above and of the exoccipitals at the sides. To this plate is attached at each lateral angle the mastoid portion of the temporal. Inasmuch as these parts have been already fully considered, it is not necessary here

to describe them. The only sutures seen on this surface are the two **occipito-mastoid sutures** situated near the lateral angles. Each suture begins below in the cleft between the paroccipital process and the mastoid process; thence it runs almost vertically to meet the lambdoidal crest, which it intersects half-way up, and ends at the asterion.

At the lower margin is the median **foramen magnum**, flanked by the **occipital condyles**. It is the only foramen visible upon this surface. The posterior surface affords attachment to many important muscles, as follows: At the lower margin, on the paroccipital process, the **digastric**; on the mastoid, the **stylo-glossus** and the **cleido-mastoid**; on the external surface of the mastoid, the **rectus capitis lateralis**; and in the deep pit above the paroccipital process and up to the lambdoidal ridge, the **obliquus capitis superior**; on the ridge

FIG. 389.



THE SKULL, POSTERIOR OR OCCIPITAL ASPECT.

above, from the middle line outwardly, the **cephalo-humeral** and the **sterno-mastoid**; below them, the **rhomboideus capitis** and the **splenius**; below these, again, the **biventer cervicis** and the **complexus**; beneath the biventer, the **rectus capitis posticus major**; and beneath that, but still confined to the superior third of the supra-occipital, is

the large area for the *rectus capitis posticus minor*. The line of attachment for the capsular ligament joins the upper ends of the condyles above the margin of the foramen magnum.

#### INTERIOR OF THE SKULL.

In order properly to examine the interior of the skull, the student will need three specimens, prepared as follows :

(1.) A skull should be sawn in two along a horizontal longitudinal plane which passes, in front, through the frontal postorbital processes, and, behind, through the occipital bone above the foramen magnum (Fig. 390).

(2.) A second skull should be bisected along a vertical longitudinal plane a little to one side of the median vertical plane. The half of the skull which exhibits the mesethmoid should be retained (Fig. 391).

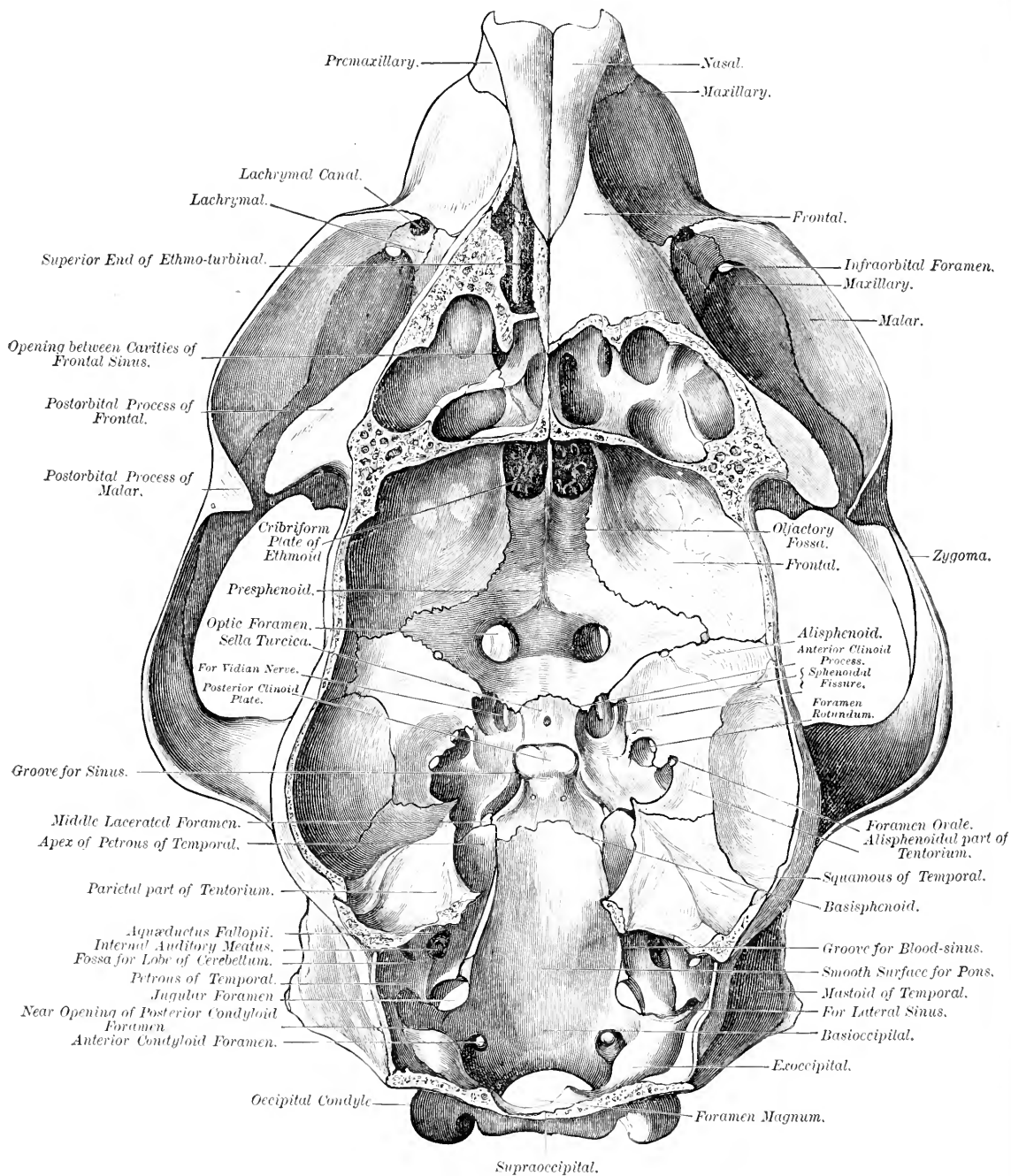
(3.) From the other half, the ethmoid, the maxillo-turbinal, and the median walls of the frontal and sphenoidal sinuses should be broken away, and a cast, in fusible metal, made of the cranial and nasal cavities (Fig. 392).

The skull encloses ten cavities. Two of these are large, unpaired, and lie in the median line ; eight are small and arranged in pairs, four on each side.

Of the two median cavities the posterior and larger is the **cranial cavity**, containing the brain, and the anterior and smaller is the **nasal cavity**, partially subdivided into two chambers containing the complicated scrolls of the ethmoid and largely devoted to the sense of smell.

Of the paired cavities four small ones are connected with the back part of the nasal cavity, one on each side above, the **frontal sinuses**, and one on each side below, the **sphenoidal sinuses**. They are contained in the frontals and the sphenoid, but do not communicate with the cranial cavity. When the facial part of the skull is removed the large anterior openings of these sinuses are seen above and below on the front aspect of the cranium proper (Fig. 200). The remaining four cavities of the skull are on each side in its lower posterior portion. They also are formed by the bones of the cranium, and are not connected with the cranial cavity, except by small canals for the passage of nerves and vessels. Of these four cavities two are the **labyrinths**, or cavities of the internal ear, and are small and hidden away on each

FIG. 390.



THE SKULL, CRANIAL CAVITY FROM ABOVE.

side in the solid substance of the petrous portion of the temporal bone, while the other two, the **tympani** or middle ears, lie on each side below them between the base of the skull and the auditory bulla. They contain the small auditory ossicles, communicate medially with the labyrinths, open to the exterior through the Eustachian opening into the pharynx, and, when the membranous drum of the ear is removed, through the external auditory meatus into the cartilaginous external ear.

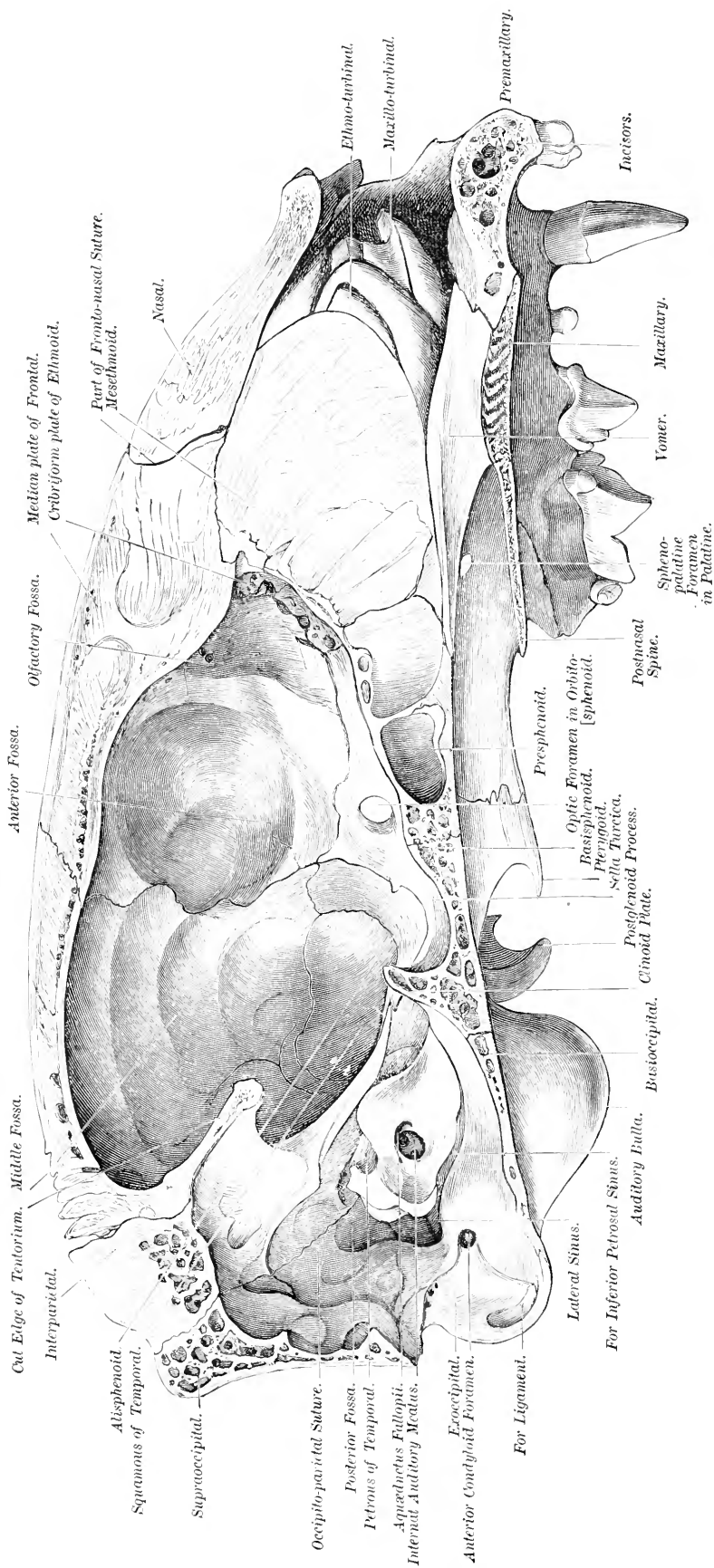
#### CRANIAL CAVITY.

The Cranial Cavity occupies that greater part of the skull which lies above and behind the orbital cavities. Inasmuch as its walls are nearly everywhere of uniform thinness, the size and general shape of the cavity are well exhibited by the exterior form. The cranial cavity is an oval chamber about twice as long as high and one-third longer than wide. From the floor, which is for the most part flat, the concave sides rise without a dividing line and curve over above to form the vaulted roof. The posterior wall is straight and nearly vertical; it is pierced at its lower part by the median foramen magnum. The anterior wall is concave from side to side and slopes forward as well as upward. It is prolonged forward as the sides of a narrow quadrate olfactory fossa which is closed in front by the cribriform plate of the ethmoid, the anterior boundary of the entire cranial cavity.

The cranial cavity is enclosed by the frontals, the parietals, the interparietal, the occipital, the temporals, and the sphenoid. These bones are so arranged that the floor is formed by the sphenoid and the occipital; the anterior wall by the frontal; the sides and roof by the frontals, the parietals, and the interparietals; and the posterior wall by the occipital only.

The cranial walls exhibit constrictions, projections, and variations in direction which divide the cavity into the olfactory and the anterior, middle, and posterior cranial fossæ. The posterior fossa is separated from the middle fossa by the sloping imperfect partition formed of the tentorial processes of the parietals; the middle fossa is well defined from the anterior fossa in front by the elevation of the floor and the change in its inclination and by lateral ridges beginning behind the optic foramina and continuing for some distance upward on the side walls. The anterior fossa is defined in front from the olfactory fossa by the abrupt constriction of the cranial walls.

Fig. 391.



THE SKULL, SIDE VIEW OF CRANIAL AND NASAL CAVITIES.



The **Olfactory Fossa**, for the olfactory lobes of the brain, is the prolongation forward of the general cranial cavity over the sinus in the body of the presphenoid, over the lower part of the nasal cavity, under the sinus in the frontal bone, and under the upper part of the nasal cavity (Fig. 392). It is quadrate, but compressed laterally, the width being less by a quarter than the height. The greatest antero-posterior length is slightly less than the height.

The **floor** is faintly concave from side to side, and slopes slightly downward in front (Fig. 390). It is formed by the coalesced presphenoid and orbitosphenoids. At its anterior end is the transverse sphenoid-ethmoidal suture, and along each side is the anterior end of the fronto-orbitosphenoidal suture.

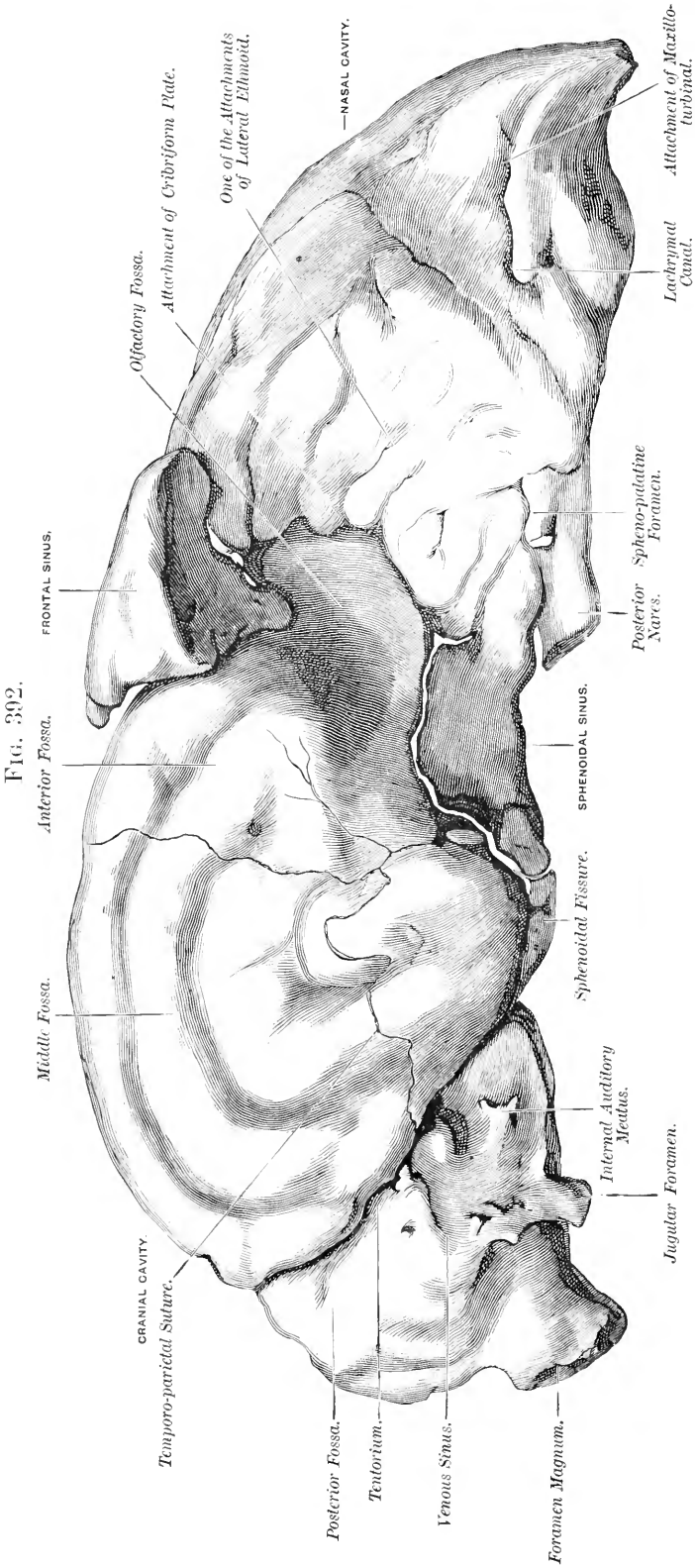
The **lateral walls** (Fig. 391) are almost flat, vertical, and parallel; they are formed by the vertical plates of the frontals. Along the arcuate anterior edge of each wall is the jagged line of attachment of the edge of the cribriform plate. Near the lower anterior angle of the lateral wall are the internal openings of at least one of the ethmoidal foramina from the orbit.

The **short roof** is convex from before backward and concave from side to side. In the middle line is a ridge formed by the lower edges of the conjoined median plates of the frontals. The roof of the olfactory fossa is also the floor of the frontal sinuses.

The **anterior wall** is concave from above downward, and is pierced by numerous foramina for the olfactory fibres. It is the cribriform plate of the ethmoid, which has been already described (page 312).

The **Anterior Fossa** occupies about the anterior third of the cranial cavity (Figs. 390, 391, 392). It is easily distinguished from the olfactory fossa in front and at its lower part from the middle fossa behind, but at the upper part it appears to be confluent with it. The posterior point on its roof, at the **bregma**, lies further forward than the posterior point on the floor, and, as the anterior walls incline forward, the whole fossa appears to be directed upward and forward.

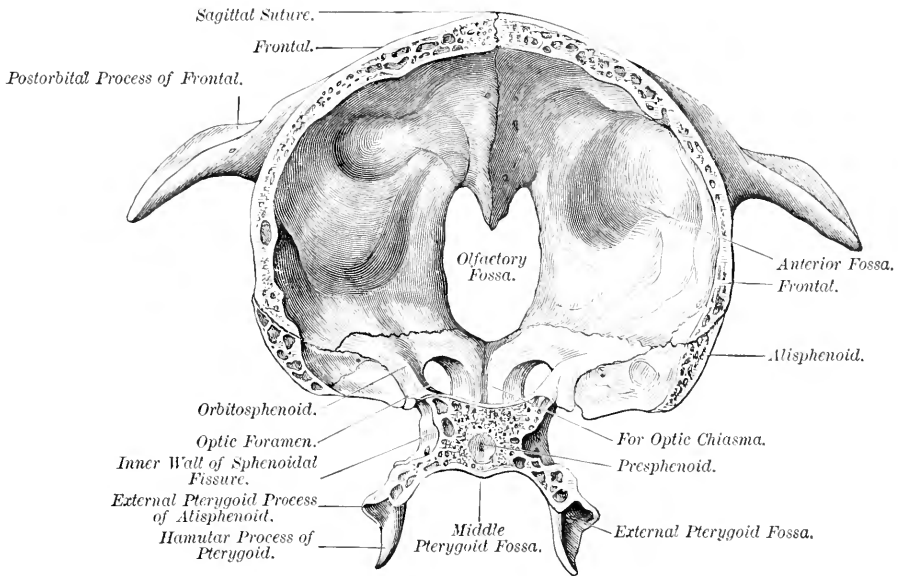
Its **floor** is on a higher plane than the floor of the succeeding fossæ; it faces somewhat backward and upward, and is continuous in front with the floor of the olfactory fossa. Its outline is that of the sphenoid,—namely, a hexagon, compressed from before backward, bounded in front by the posterior limit of the floor of the olfactory fossa and on each side by the fronto-sphenoidal sutures and behind



METAL CAST OF THE CAVITIES OF THE SKULL, RIGHT SIDE, AUDITORY BULLA REMOVED.

by the **prespheno-basisphenoidal** and **orbitospheno-alisphenoidal** sutures. The surface is convex from before backward and slightly concave from side to side. Behind the middle, on each side, is the **optic foramen**, and behind this, separated by the **anterior clinoid**

FIG. 393.



TRANSVERSE VERTICAL SECTION OF THE SKULL THROUGH THE SPHENOIDAL FISSURE, SEEN FROM BEHIND.

plate, is the **sphenoidal fissure** (Fig. 393). The anterior and lateral walls and the roof are contributed by the frontals.

The **anterior wall** (Fig. 393) occupies the entire width of the skull, and on each side of the olfactory fossa faces backward, upward, and slightly inward. The **lateral walls** are narrow below and wide above; they face inward and slightly backward. They are impressed above by shallow **fossæ** for the anterior cerebral convolutions, and at the posterior lower part by an arborescent **arterial groove**.

The **roof** is directed upward and forward; it is narrow in front, wide behind, and evenly arched. In the middle line, at the sagittal suture, is a ridge for the attachment of a tough membrane of the brain, known as the **falx cerebri**. The roof also is impressed by the cerebral convolutions.

The **Middle Fossa** is the largest of the four. It is longer above than below, inasmuch as its anterior point on the roof lies nearly over its anterior point on the floor, while the upper posterior point lies

over the middle of the antero-posterior length of the posterior fossa (Fig. 392). The middle fossa appears to slope in the direction opposite to that assumed by the anterior fossa, or upward and backward. It is defined in front by the posterior boundaries of the middle fossa, and behind by the tentorium.

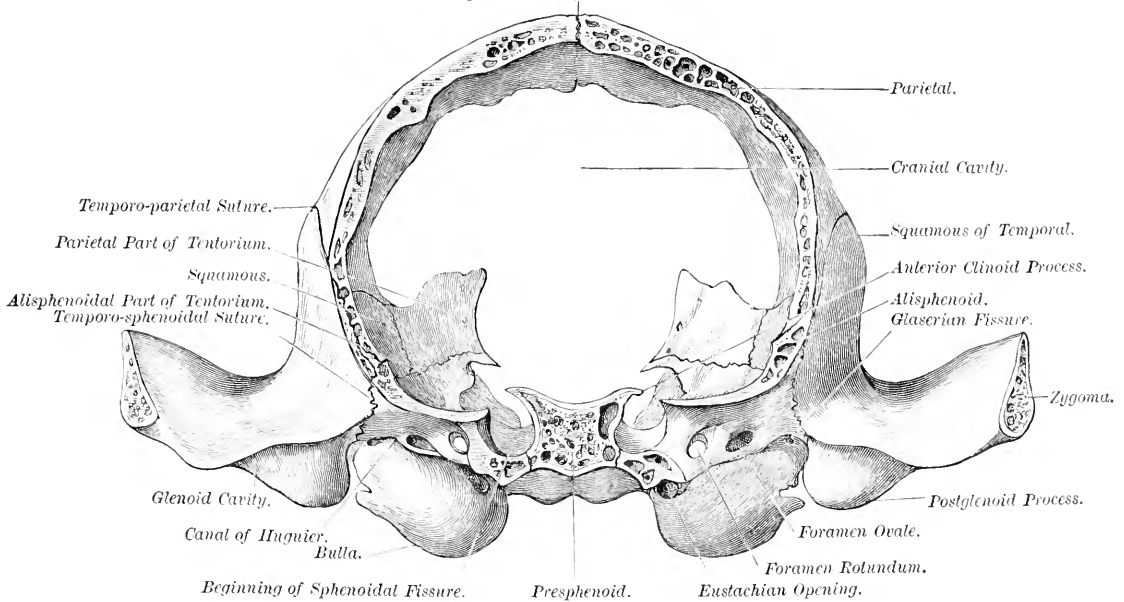
The **floor** (Fig. 390) is short, but extends across the skull and turns sharply up at the sides into the lateral walls. It is formed by the basisphenoid, the alisphenoids, and the squamous of the temporals. At its posterior part in the middle line is the **dorsum sellæ**, in front of which is the **sella turcica**, or pituitary fossa, bounded in front by the elevated middle part of the anterior fossa. On each side of the sella turcica is an oval flattened area which leads forward and outward into the **sphenoidal fissure**, the **foramen rotundum**, and the **foramen ovale**. The lateral fourths of the floor are on a slightly higher plane than the middle portion, overhanging it and the foramina by sharp edges continued upward and backward as the edges of the large central emargination in the tentorium. These elevated portions are concave from before backward and transversely, and are continuous behind with the posterior or tentorial wall. Each exhibits in the line of the **squamosphenoidal suture** a longitudinal ridge, which separates two longitudinal impressions for cerebral convolutions. Each exhibits also a transverse suture between the alisphenoidal and parietal parts of the tentorium.

The concave **lateral walls** (Figs. 391, 394) are short below, long above, and arch upward to form the **roof**. They are composed of the upper parts of the squamous of the temporals for a short distance below, but principally of the extensive parietals. The lateral walls and the roof exhibit impressions for the cerebral convolutions. An arborescent line or **groove** for the middle meningeal artery is seen on the lower posterior part of each lateral wall. The **falx cerebri** is attached along the middle line of the roof.

The **posterior wall**, or tentorium, slopes backward and upward; it is strongly convex from side to side and from above downward. In its lower part is a large median opening which converts the 'posterior wall of the fossa into little more than a long shelf, and permits the union of the cerebral and cerebellar portions of the brain.

The **Posterior Fossa** (Figs. 390, 391, 392) is much smaller than the middle fossa. Its antero-posterior length is shorter above and below than in the middle.

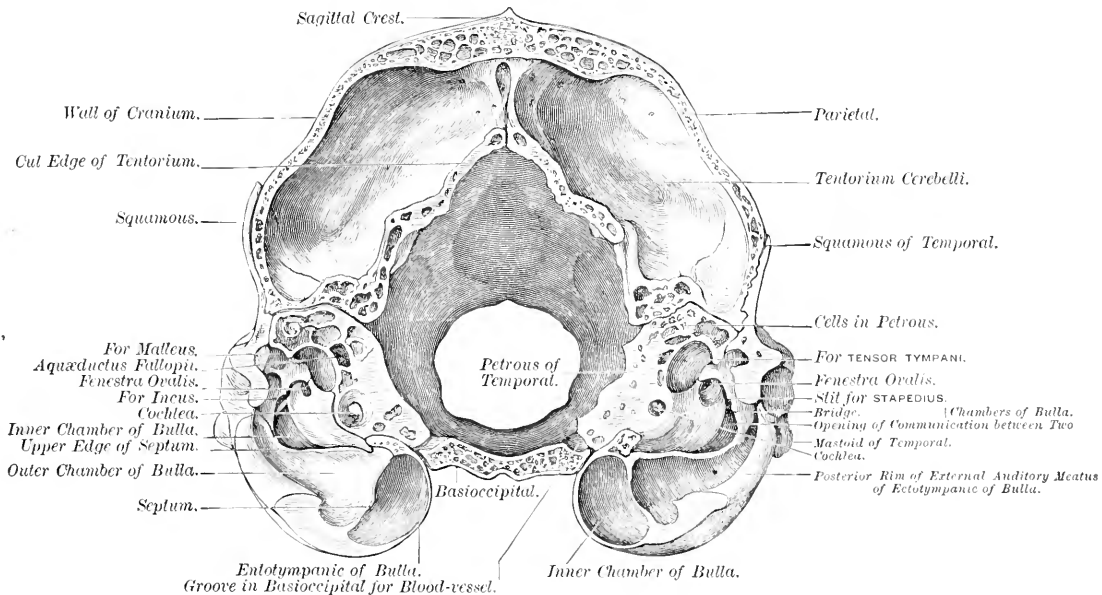
FIG. 394.

*Sagittal or Interparietal Suture.*

TRANSVERSE VERTICAL SECTION OF SKULL THROUGH SPHENOIDAL FISSURE.

The anterior wall formed by the tentorium slopes backward and upward and becomes the anterior part of the roof. It is concave from side to side, and marked by impressions for the cerebellum. It turns

FIG. 395.



TRANSVERSE VERTICAL SECTION OF SKULL THROUGH EXTERNAL AUDITORY MEATUS.

back at each outer edge to form the anterior and greater portion of the concave **lateral wall**, the posterior lower portion of which is contributed by the parietal and the mastoid of the temporal. The **posterior wall** is nearly vertical, and is the occipital plate of the occipital bone. At its outer edges are seen the **occipito-mastoid** and **occipito-parietal** sutures; above, it joins the interparietal. The posterior wall is marked by the convolutions of the cerebellum.

The arched **roof** is formed by the tentorium, the parietals proper, and the interparietal; it exhibits the dividing sutures seen on the exterior of the skull.

The **floor** is extensive, but filled on each side by the prominent petrous portion of the temporal (Figs. 391, 395). The central part is flat or gently concave, and is the basilar plate of the occipital which supports the portion of the brain known as the pons. In front, a little behind the dorsum sellæ, is the transverse **basilar** or **spheno-occipital suture**, at the outer end whereof, on each side, at the tip of the petrous, is the minute **middle lacerated foramen**. In some specimens this foramen is continued backward as a slit between the basioccipital and the posterior border of the petrous. Along the inner edge of the petrous is the **groove** which lodges the venous canal called the **inferior petrosal sinus**; it leads into the large **jugular foramen**. Another groove passes upward and backward along the posterior edge of the petrous and continues up the lateral wall to enter the parietal bone; it is the **groove** for the **lateral sinus**. Behind the jugular foramen and nearer the median line is the **anterior condyloid foramen**, and far behind this again the **posterior condyloid foramen**. The posterior margin of the floor of the posterior fossa is deeply emarginate, and is the lower margin of the **foramen magnum**. On each side, the large petrous portion of the temporal occupies the anterior lateral angle. Its anterior surface is almost entirely covered by the tentorium. Its posterior surface faces inward, backward, and upward, and exhibits the **internal auditory meatus** with its associated slit-like beginning of the **aquæductus Fallopii**. Above these is the deep pit for the flocculus, or appendicular lobe, of the cerebellum, bounded behind by the elevation for the superior and posterior semicircular canals. Along the line where the posterior surface of the petrous joins the tentorium is the **groove** for the **superior petrosal sinus**. The posterior upward projection belongs to the mastoid.

## NASAL FOSSÆ.

The anterior part of the conjoined frontals is united with the bones of the face to form a thin-walled nasal chamber, almost completely filled by the ethmoid, the maxillo-turbinal, and the vomer. Indeed, the investing bones are in great measure moulded on the outer surface of the lateral ethmoids, and a cast of the nasal chamber has the form and nearly the size of the ethmoid, vomer, and turbinal when removed from the skull (Fig. 392). If the nasal chamber be bisected longitudinally, and the mesethmoid, the median plate of the frontal, the lateral ethmoid, and the maxillo-turbinal be carefully broken away, its investing walls become visible (Fig. 398). The nasal chamber is narrower above than below, and narrower in front and behind than in the middle. Its greatest height, which is behind, is but a fifth less than its greatest median antero-posterior length below. Its greatest width is on the floor, on a transverse line joining the lower edges of the lachrymal bones, and is about a third less than its length. It is divided by a median vertical partition, composed of the frontal, the nasal, the mesethmoid, the vomer, and plates of cartilage, into equal halves known as the *nasal fossæ* or *nasal sinuses*. Each nasal fossa, therefore, contains a lateral ethmoid and a maxillo-turbinal. It presents inner, outer, and posterior walls, a floor, a roof, and anterior and posterior openings.

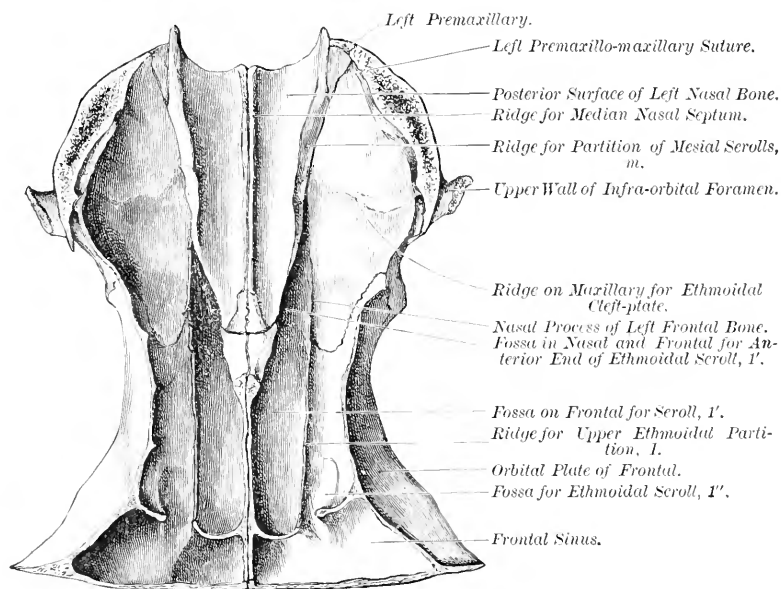
The **inner** or **median wall** of each nasal fossa (Fig. 391) is vertical and flat, but may be bowed inward or outward. It is high behind and low in front, and is formed above by the median plates of the frontal and the nasal, for the larger part of its extent by the mesethmoid with its forward continuation, the septal cartilage, and at the lowest part by the vomer. The lower edge of the partition is higher behind, where it is free, than in front, where it is attached to the middle line of the floor of the general nasal chamber. The space under its posterior part between the vomer and the palatines permits, even in the natural state, one nasal fossa to communicate with the other.

The **posterior wall** of the nasal fossa is convex from above downward, and is almost exclusively formed by the anterior surface of the cribriform plate of the ethmoid. It gives attachment to the posterior ends of the scrolls of the lateral ethmoid. Above the cribriform plate the frontal forms a small upper part of the posterior wall, which is

pierced by a foramen for the tip of the upper outer scroll of the lateral ethmoid. Below the cribriform plate is the opening leading backward into the sinus in the body of the presphenoid, which is filled by the lowest scroll of the ethmoid. The cribriform plate exhibits the small olfactory openings.

The floor of each nasal fossa is oblong, and is more than twice as long as wide (Fig. 397). It is formed by the premaxillary bone and the palatine processes of the maxillary and palatine bones. Its median line is straight, and for the anterior two-thirds is elevated into a **crest** to give attachment to the vomer and the septal cartilage. At its outer arcuate edge the floor turns up abruptly behind into the outer wall. The emarginate posterior edge is the lower edge of the posterior nares. The floor is almost flat, and slopes slightly downward at the posterior part. In front, near the inner border, is the large oval **anterior palatine foramen**; beyond this is the elevated transverse ridge which forms the lower lip of the anterior naris. The floors of the two nasal fossæ are confluent at the posterior third, behind the attachment of the vomer.

FIG. 396.

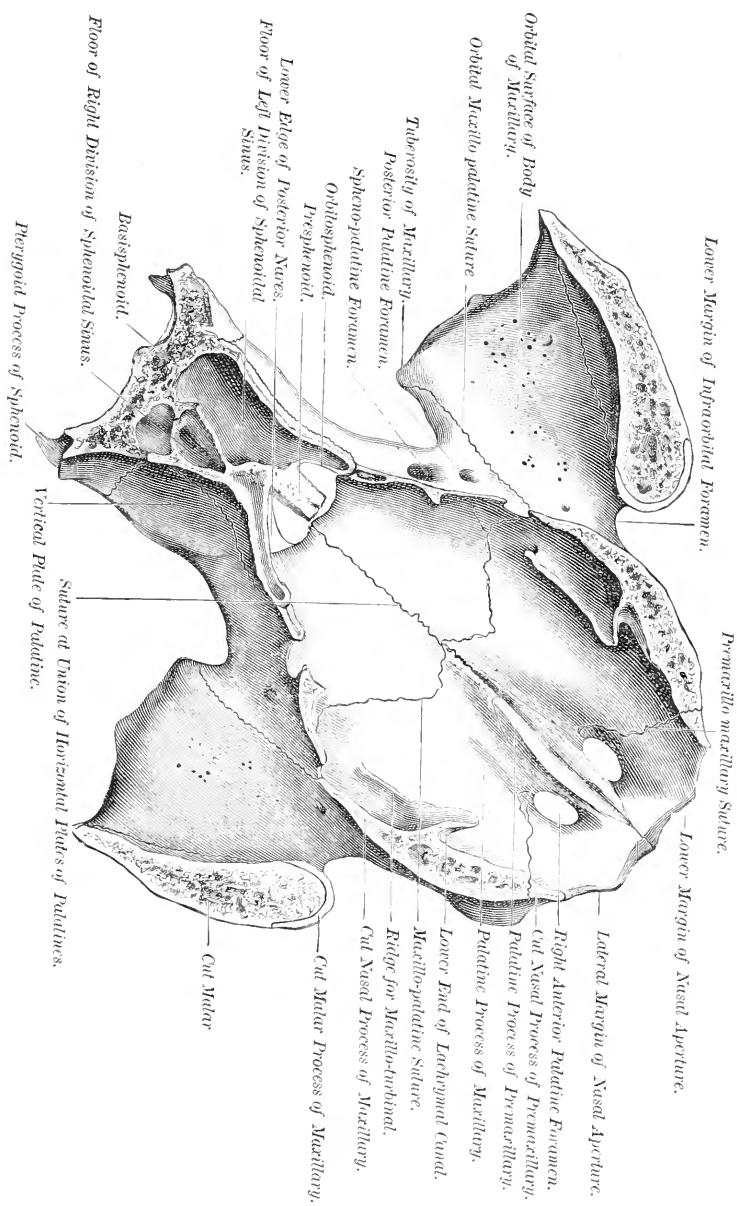


ROOF AND PART OF ANTERIOR WALL OF NASAL CHAMBER; ETHMOID REMOVED.

The roof (Fig. 396) of each nasal fossa consists of two parts,—a shorter, narrow anterior part, consisting of the concave posterior surface of the nasal bone, and a longer and wider posterior part, which is the under surface of the horizontal portion of the frontal lying

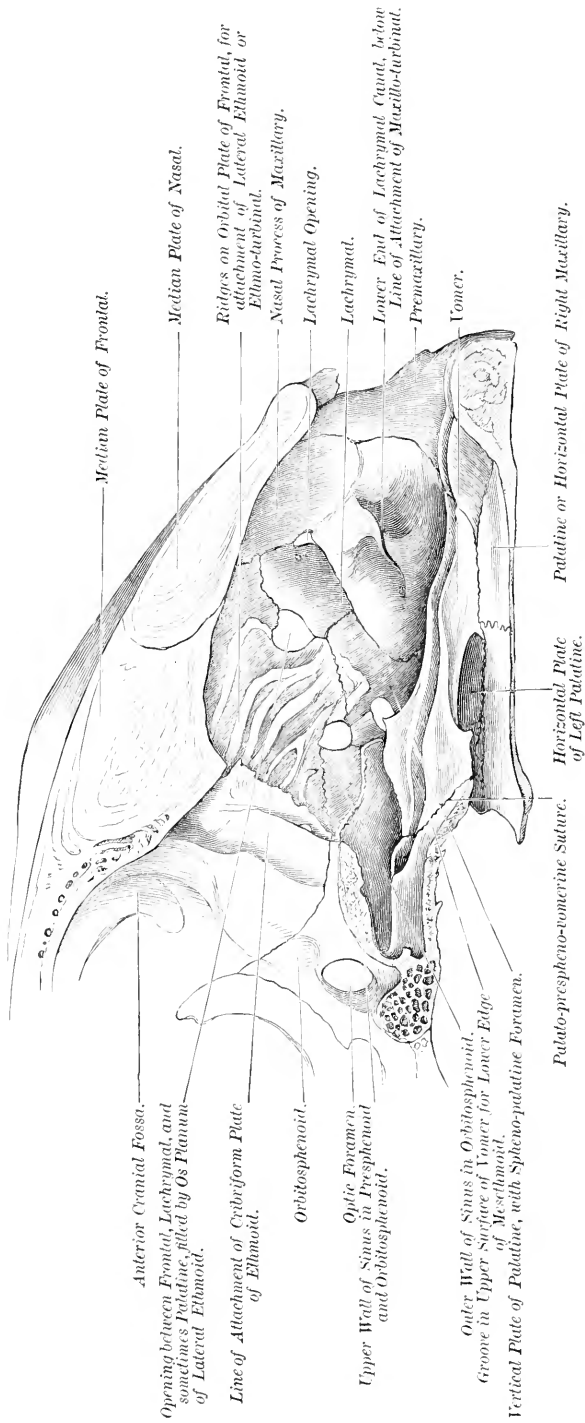


FIG. 397.



FLOOR OF NASAL FOSSAE; ETHMOID AND MAXILLO-TURBINALS REMOVED.

FIG. 398.



OUTER WALL OF LEFT NASAL CAVITY FROM WITHIN, ETHMOID REMOVED.

between the orbital and median plates. This latter part has been called the external frontal sinus, and because of the close union of the partition of the mesial ethmoidal scrolls with the edge of the nasal, and the union of the lower edge of the median plate of the frontal with the upper edge of the nasal septum, it is apparently shut off from the rest of the nasal fossa and is not seen in the ordinary median longitudinal vertical section. It is exposed by breaking away the median plate of the frontal. It is wider behind than in front, where it is continued into the small fossa between the nasal process of the frontal and the excavated upper part of the outer surface of the nasal bone. This fossa receives the anterior end of the upper ethmoidal scroll.

By the **outer wall** is meant not the wall formed by the inner surfaces of the scrolls of the lateral ethmoid and the maxillo-turbinal facing the mesethmoid, but the wall to which these are attached, and which is exposed only by removing them (Fig. 398). To expose the upper portion, the median plate of the frontal also should be cut away. When this is done, the outer wall is seen to be triangular in shape, with the **lower border** straight. The **posterior border** is not so long as the lower, and is emarginate, but its upper point lies nearly over its lower point. The **upper border** is arcuate and directed from behind downward and forward. The **anterior angle** is truncated, and the small anterior border thus formed is the side margin of the anterior naris. The surface slopes outward as it descends from the roof, making the nasal fossa widest below. It is concave from before backward, and the line of the deepest concavity begins at the upper posterior part and arches forward and downward to meet the lower border a little anterior to its middle point. The portion of the surface in front of this line faces backward, inward, and downward; the portion behind the line faces forward, inward, and downward. Furthermore, the anterior part is concave from above downward and is composed of the inner surface of the nasal processes of the premaxillary and maxillary. The almost vertical **premaxillo-maxillary suture** is seen a little behind the emarginate anterior border. This anterior part of the surface is bounded above by the prominent, slightly rolled outer edge of the posterior surface of the nasal, to which the partition between the mesial scrolls of the ethmoid is attached. The posterior boundary is the line already mentioned which lies approximately along the suture between the maxillary in front and the frontal and

lachrymal behind. At the upper part of the maxillary portion are several oblique lines for the attachment of the anterior ends of the upper ethmoidal scrolls. A little below the middle is a prominent line running from before backward; at its middle another line begins and runs obliquely downward and backward to the floor of the fossa. To the horizontal line and to the lower oblique line the maxillo-turbinal is attached. Under the posterior half of the horizontal line, between the maxillary and the maxillo-turbinal, is the **nasal canal** leading from the lachrymal groove of the orbit to the nasal fossa. An artificial opening is often seen at the **maxillo-lachrymal suture**, but its anterior true opening lies under the horizontal line at the upper end of the oblique line.

The surface behind the line of greatest concavity is slightly convex from above downward, and is formed above of the frontal, and below, from before backward, of the lachrymal and the palatine. The portion contributed by the frontal turns above into the roof. It is marked below by the vertical, jagged line of attachment of the cribriform plate, and by six curved lines which are directed downward and forward from this line and afford attachment to the partitions between the ethmoidal scrolls. At its lower edge is the almost straight suture between the frontal and the bones below it. These bones form approximately the lower third of this portion of the outer wall of the nasal fossa; very little of the orbito-sphenoid is seen at the posterior part. The lachrymal forms slightly less than the anterior half; then follows the vertical plate of the palatine, which is pierced by the sphenopalatine foramen and is continued back under the orbito-sphenoid as the lateral wall of the posterior naris.

#### GROWTH OF THE SKULL.

The rate of growth of the skull was obtained by observing the degrees of its development in cats of the following ages: shortly before birth, at birth, at three days, at seven days, at eleven days, at fifteen days, at twenty-three days, at thirty days, at thirty-five days, at forty-four days, at sixty days, at seventy days, at eighty days, at eighty-six days, at ninety days, and at one hundred and twenty days. Seven of these cats were from two litters of the same mother and were reared under similar conditions. From the winter litter were obtained those eleven and forty-four days old; from the spring litter, those thirty, sixty, and seventy days old; from the summer litter, those twenty-three

and eighty-six days old. Six cats were from two litters of another mother. From the spring litter were taken those one, ninety, and one hundred and twenty days old; from the summer litter, those three, fifteen, and thirty-five days old. The remaining cats were from different litters of different mothers. It will be noticed in the table (page 506) that the skull of the cat eighty days old is smaller than several of the younger skulls; this was owing to the unfavorable conditions under which the animal was reared; to particularly favorable conditions must be attributed the greater development of the skull of the cat sixty days old. Hence it must not be supposed that every cat will present, at the age given, the exact degree of cranial development illustrated in the figures; these are introduced to enable the student to fix approximately by cranial characters the age of kittens before the eruption of the permanent dentition. I have begun the series with the skull shortly before birth; it is possible that some kittens at birth may present no greater cranial development than was therein observed.

The general changes which take place in the skull from birth to adult life are,—increase in size, changes in form and in the relative proportions of different parts, and the gradual ossification of cartilaginous and membranous portions.

The increase in length (page 506) from the opisthion, on the posterior rim of the foramen magnum, to the alveolar point, on the alveolar border of the premaxillaries, is from thirty to seventy-nine millimetres; the increase in cranial height, measured on the inside of the cranial cavity from the suture between the presphenoid and basisphenoid to the bregma, at the junction of the sagittal and coronal sutures, is from fifteen to twenty-six millimetres. As the skull increases in length, the length of the face relatively to the length of the whole skull increases and the relative length of the cranium decreases. The relations may be shown by the facial length index  $\left(\frac{\text{facial length} \times 100}{\text{length of skull}}\right)$ , which before birth is 30 and at adult life is 40.5; and by the cranial length index  $\left(\frac{\text{cranial length} \times 100}{\text{length of skull}}\right)$ , which before birth is 66.6 and at adult life is 55.6.

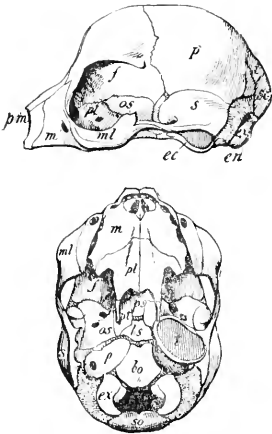
It will be observed that in the younger skulls the anterior part of the cranium presents prominent frontal eminences, below which the profile of the face is concave; as the skull develops, these eminences

become less conspicuous and retreat almost to the bregma; the profile of the face becomes slightly convex. If the height of the cranial cavity be compared with its length by means of the cranial height index  $\left(\frac{\text{cranial height} \times 100}{\text{cranial length}}\right)$ , we observe that as the skull develops the index decreases from 75 to 59 millimetres.

The skull is developed partly from cartilage, partly from membrane; the cartilage occupies the base and lower parts of the sides of the cranium, and gives rise to the occipital, the greater part of the temporals, the sphenoid, the ethmoid, and the maxillo-turbinals.

The skull shortly before birth (Fig. 399) is characterized by an almost globular form, due to the relatively large cranium and to the small size and inferior position of the face.

FIG. 399.



THE SKULL, BEFORE BIRTH.  
(Natural size.)

The greater number of the constituent bones are more or less ossified; a few are still represented by membrane and cartilage. Because of the extreme delicacy of the ossifications and the firm attachments of muscles and fibrous tissue to the bones and cartilages, especially at the base of the cranium, the student must exercise great care in preparing the skull for study.

The occipital bone is represented by four distinct pieces separated by strips of cartilage. Of these the supraoccipital is oval, convex, and smooth; the basioccipital is long, narrow, and hexagonal; and the exoccipitals are crescentic, and bear flattened condyles but no distinct paroccipital processes. The interparietal is well ossified; it is larger than the supraoccipital. The parietals are externally strongly convex; internally they bear narrow curved plates representing the tentorial processes. On each side of the skull the supraoccipital, exoccipital, interparietal, parietal, and temporal are separated by a large area of cartilage continuous below with the petrous portion of the temporal; this cartilage fills the posterior lateral fontanelle; its lower part contains the semi-circular canals. There is no true posterior fontanelle, as in man, at the lambda between the supraoccipital and the parietals.

In the temporal bone the squamous is ossified (from membrane),

but is not united to the petrous or the tympanic. The ectotympanic of the auditory bulla is a delicate ring of bone supporting the edge of a large tympanic membrane; the endotympanic is a membranous sac. The anterior part of the petrous is entirely ossified, except at a circular area on the inferior surface near the apex; the posterior or mastoid portion is cartilaginous. The malleus is continuous with a rod of cartilage, the so-called Meckel's cartilage, which forms the first trace of the lower jaw and around which the bony mandible is developed from membrane. The petrous appears in the interior of the cranium as an inflated pear-shaped mass of porous bone; the internal auditory meatus and the hiatus Fallopii are very large; the aquæductus vestibuli opens in a long groove on the posterior surface; behind this groove the petrous is still cartilaginous.

The sphenoid is well formed in bone, and exhibits all its parts. The anterior sphenoid is distinct from the posterior sphenoid; the presphenoid, however, has united with the orbitosphenoids. The sphenoidal sinuses are already present. The basisphenoid is separated from the alisphenoids and the pterygoids. The tip of the orbitosphenoid is truncated, and exposes a membranous anterior lateral fontanelle at the pterion between the frontal, parietal, temporal, and sphenoid bones. An area of cartilage between the sphenoid and the petrous and pierced for blood-vessels represents the middle lacerated foramen.

The frontal bones are very convex; there are, as yet, no frontal sinuses. The frontal and malar postorbital processes are small tubercles. There is no true anterior fontanelle at the bregma.

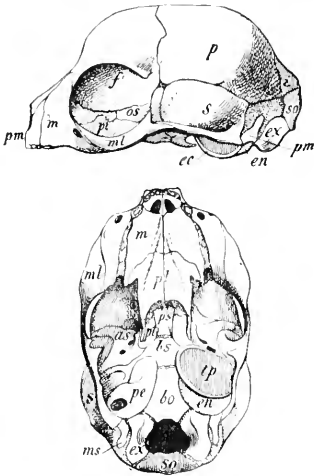
On the inner wall of the orbit, below the frontal and above the palatine and maxillary, is a long strip filled by the membrane covering the lateral ethmoid. The lachrymal exhibits only a narrow line of ossification along its anterior border.

The vomer is for the greater part ossified. The maxillo-turbinal is cartilaginous, except for a small centre of ossification in the partition medial to the lachrymal canal.

The lateral ethmoids consist of a few folds of cartilage in which have appeared several bony nodules at the anterior end of the future fourth piece, in scrolls 4 and 4' (Fig. 219), and a small nodule in the medial part of the sixth piece. The mesethmoid and cribriform plate are represented by cartilage. The palatines, maxillaries, premaxillaries, and nasals are ossified.

In the skull at birth (Fig. 400) the supraoccipital shows a faint lambdoidal crest; the paroccipital processes begin to appear. The

FIG. 400.



THE SKULL, AT BIRTH.  
(Natural size.)

mastoid portion of the petro-mastoid of the temporal is visible in the lower part of the posterior lateral fontanelle as a club-shaped rod of bone extending upward and backward. The ectotympanic ring is stouter; the entotympanic sac has become cartilaginous. Viewed from the cranial cavity, the petrous is seen to have ossified behind the appendicular fossa, around the superior semicircular canal and a small part of the posterior semicircular canal. The tentorial process of the parietal has grown wider.

On the under surface of the sphenoid there are still distinct traces of the pterygo-alisphenoidal sutures. The fontanelle at the pterion and the strip of membrane on the inner wall of the orbit are well developed. The anterior ossification of the lachrymal has increased to a narrow crescentic band.

The ossifications in the lateral ethmoid at the end of the fourth piece, in the terminal medial part of scrolls 4 and 4' (Fig. 219), have extended laterally and upward along the posterior boundary of the ethmoidal cleft, and also slightly upward into the anterior ends of the first and second pieces. The ossification in the sixth piece has increased in size. A new separate and distinct centre has appeared on the medial side of the seventh piece. The anterior end of the mesial piece, including part of the cleft plate, appears to contain some osseous elements. The fifth piece is entirely cartilaginous.

The skull at seven days (Fig. 401) does not differ decidedly from the skull at birth.

The mastoid has extended further upward into the fontanelle. The squamous, petro-mastoid, and tympanic are still separate elements; the ectotympanic ring has grown thicker, the endotympanic sac is cartilaginous. The ossification of the petro-mastoid has extended further behind the appendicular fossa, which is very large and widely open below; the semicircular canals are very plainly outlined, and almost completely surrounded by bone.



The pterygo-alisphenoidal suture traverses the external pterygoid fossa from the anterior to the posterior end. The anterior lateral fontanelle persists; the membranous area in the inner wall of the orbit is narrowed by the growth of the neighboring bones. The upper and posterior part of the lachrymal is membranous. In this skull, as in many other young skulls, the orbitosphenoid is pierced by a small temporary foramen anterior to the optic foramen; and a fissure in the ethmoidal plate of the palatine extends upward from the spheno-palatine foramen.

The ossification in the fourth piece of the lateral ethmoid has extended to the plate behind the cleft and half-way up the first and second pieces. The lower

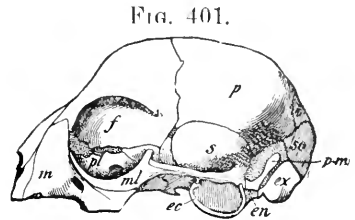
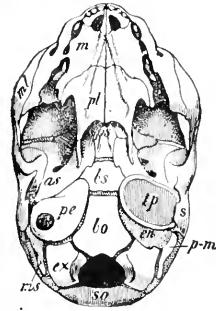
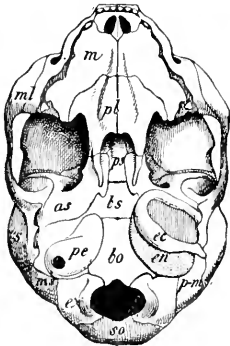
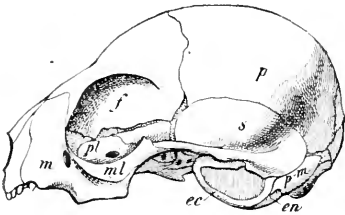


FIG. 401.



THE SKULL, SEVEN DAYS AFTER BIRTH.  
(Natural size.)

FIG. 402.



THE SKULL, ELEVEN DAYS AFTER BIRTH.  
(Natural size.)

part of the mesial piece, including its

entire cleft plate, is ossified, but is as yet separate from the other parts. The ossifications in the sixth and seventh pieces have increased in size, but are still separate from each other and from the fourth piece. A small separate centre now appears at the extreme anterior end of the fifth piece. All the scrolls of the lateral ethmoid are very simple: even that one of the fourth piece which later will subdivide to form the mass of small anterior scrolls 4<sup>m</sup> (Fig. 306) is a single plate which closely resembles the human middle turbinate bone in being deeply concave on the lateral surface.

In the skull at eleven days (Fig. 402) the supraoccipital is larger than the interparietal. The petromastoid has increased in length, and so greatly in width that it touches the squamous and parietal in front and the exoccipital behind; hence

the posterior lateral fontanelle is reduced to a small quadrangular cartilaginous area between the supraoccipital, exoccipital, parietal, and petro-mastoid.

The ectotympanic of the temporal is now a stout ring; the entotympanic is still cartilaginous. When the petrous is examined from the interior of the cranium, the superior and posterior semicircular canals are seen outlined in bone almost as plainly as in the drawing from the metal cast of the labyrinth (Fig. 160). The aquæductus vestibuli opens on the posterior surface at the anterior end of a deep notch in the posterior border.

The anterior lateral fontanelle is present; in the specimen from which Fig. 402 was drawn, it extended downward as a slit between the squamous portion of the temporal and the orbitosphenoid. The inner wall of the orbit exhibits the narrow band of membrane. The external pterygoid fossæ are divided by the pterygo-alisphenoidal sutures. The true frontal sinuses are beginning as clefts in the posterior wall of the external frontal sinus.

The eight pieces of the lateral ethmoid are all more or less ossified; they are united in front and below, but are separate above. The ossifications in the lower six pieces have extended upward almost to the cribriform plate, which, together with the mesethmoid, is still cartilaginous. The cartilage of the maxillo-turbinal has been almost entirely replaced by bone. The ethmoidal scrolls are but slightly subdivided.

The skulls at fifteen and twenty-three days stand in point of development between the skulls at eleven and thirty days. At fifteen days the entotympanic is ossified and the floor of the appendicular fossa closed.

The skull at thirty days (Fig. 403) shows a distinct advance in development.

The posterior lateral fontanelle has disappeared by the upward growth of the mastoid part of the petro-mastoid. The squamous is beginning to unite with the petrous and the tympanic. The ectotympanic ring has increased in thickness, hence the diameter of the external auditory meatus is reduced; the entotympanic has ossified. On the posterior surface of the petro-mastoid, the internal auditory meatus has become smaller, the appendicular fossa shallow, and the posterior semicircular canal less clearly defined. The aquæductus vestibuli opens on the posterior border. The posterior prolongation of the

petro-mastoid is complete. The tentorial process of the parietals has assumed its adult proportions.

The anterior lateral fontanelle has disappeared, as has also the posterior part of the pterygo-alisphenoidal suture. The orbital wall is completely ossified. The frontal sinus is still rudimentary; the sphenoidal sinuses are well developed and contain the lowest ethmoidal scrolls.

The lateral ethmoid has reached its adult form; it does not cover the maxillo-turbinal, however, and the scrolls are less complicated. The fourth piece is still joined to the cribriform plate by cartilage. The cribriform plate has ossified, and a bony strip, two millimetres in width, appears in the posterior end of the mesethmoid. With the exception of the small first upper molars, all the milk teeth are in place.

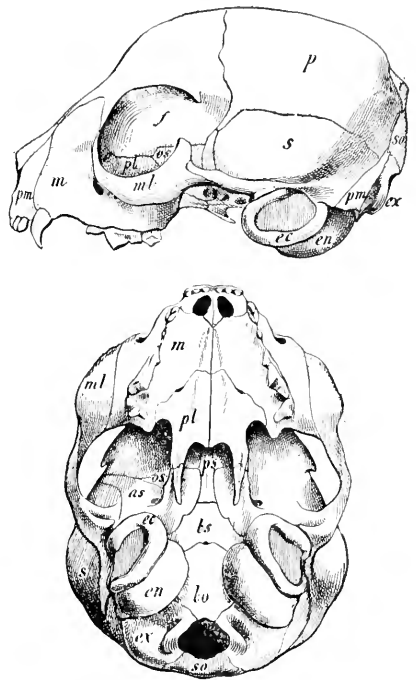
The skull at thirty-five days does not differ noticeably from the preceding skull; the ectotympanic has joined the squamous.

The skull at forty-four days (Fig. 404) does not differ in a marked degree from the skull at thirty days. The interparietal is much smaller; the posterior part of the petro-mastoid is larger; the external auditory meatus is reduced by the increased width of the ectotympanic; the entotympanic is more strongly ossified and is joined more closely to the ectotympanic.

There are now no fontanelles, and there is merely a trace of the anterior end of the pterygo-alisphenoidal suture. The postorbital processes are larger. The frontal sinuses are well developed.

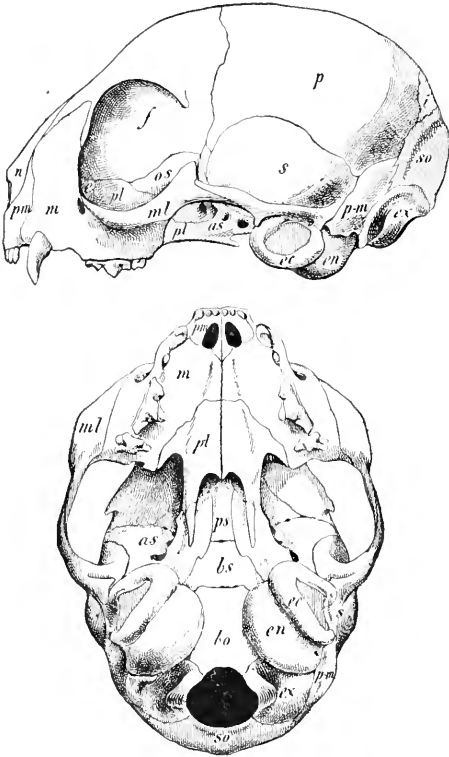
The scrolls of the lateral ethmoid are joined by bone to the cribriform plate; the lower scrolls are more distinctly subdivided and cover a larger part of the maxillo-turbinal. The diameter of the bony mesethmoid, measured at right angles to the cribriform plate, has now reached three millimetres.

FIG. 403.



THE SKULL, THIRTY DAYS AFTER BIRTH.  
(Natural size.)

FIG. 404.



THE SKULL, FORTY-FOUR DAYS AFTER BIRTH.  
(Natural size.)

then uncovered and forms the os planum.

The table on page 506 contains principally such measurements of the skull as exhibit the relative sizes of the cranium and face at the different ages already studied. They were taken upon longitudinally bisected skulls as follows :

The distance from the opisthion, on the posterior margin of the foramen magnum, to the alveolar point, at the middle of the anterior edge of the premaxillary alveolar border, is the length of the cranial and nasal cavities.

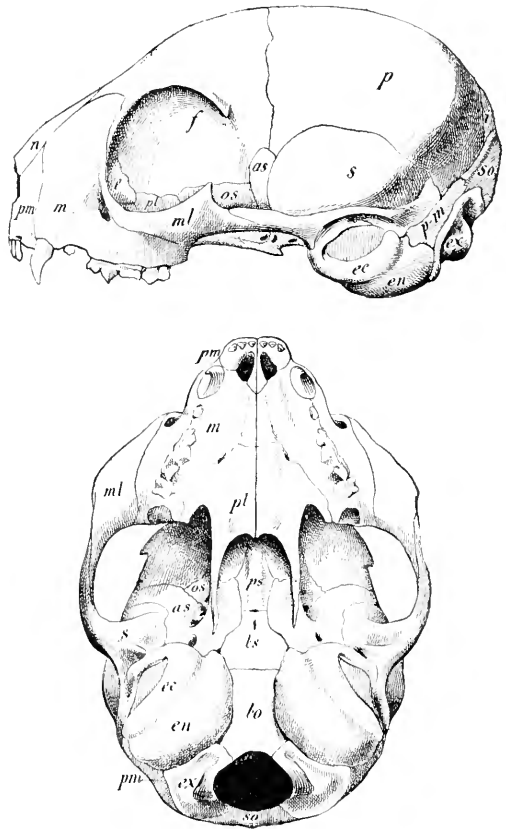
The long diameter of the cranial

The subsequent growth of the skull from forty-four days to adult life is marked by an increasing density of the bones and by a change in form, produced by the relatively greater increase in the length of the face and a relative decrease in the length and height of the cranium.

The scrolls of the lateral ethmoid increase in size and complexity, and the ossification in the mesethmoid extends gradually forward.

In some specimens the upper posterior part of the lachrymal does not ossify ; the lateral ethmoid is

FIG. 405.

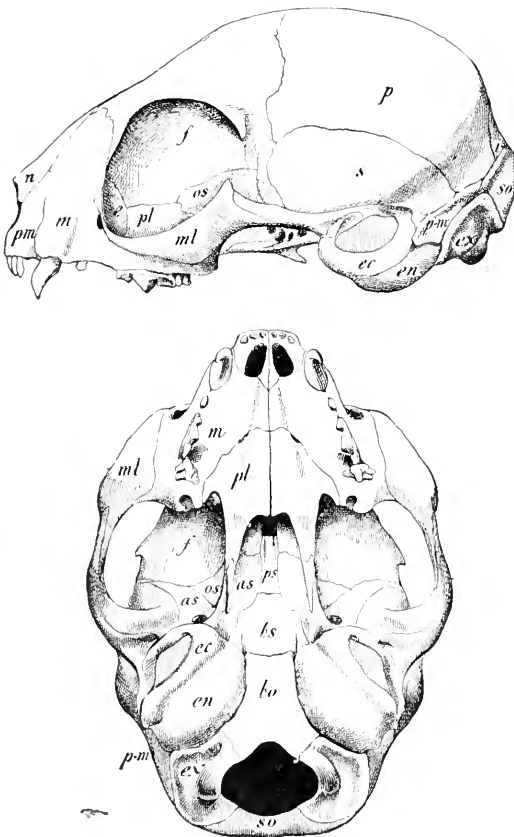


THE SKULL, SIXTY DAYS AFTER BIRTH.  
(Natural size.)

cavity is, approximately, the distance along the middle line, from the opisthion to the point where the posterior edge of the cribriform plate joins the anterior edge of the anterior sphenoid.

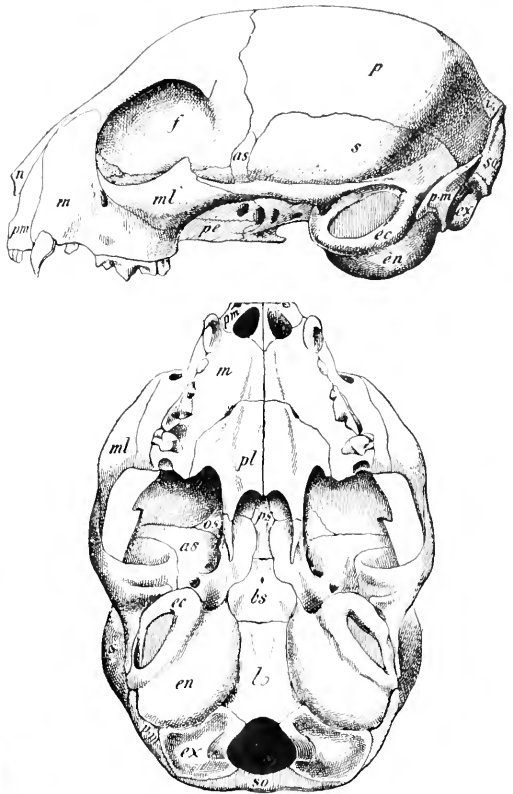
This diameter does not include the basal length of the small olfactory fossa; if it is desired to add this, the maximum long diameter of the cranial cavity is taken from the opisthion to the most anterior point of the cribriform plate, which is the point of its greatest convexity forward.

FIG. 407.



THE SKULL, EIGHTY DAYS AFTER BIRTH.  
(Natural size.)

FIG. 406.



THE SKULL, SEVENTY DAYS AFTER BIRTH.  
(Natural size.)

It will be observed that the distance from this point to the posterior edge of the cribriform plate varies in the different skulls, owing to variations in the slope and convexity of the plate itself.

The maximum basal length of the nasal cavity is the distance from the alveolar point to the anterior edge of the intracranial surface of the anterior sphenoid.

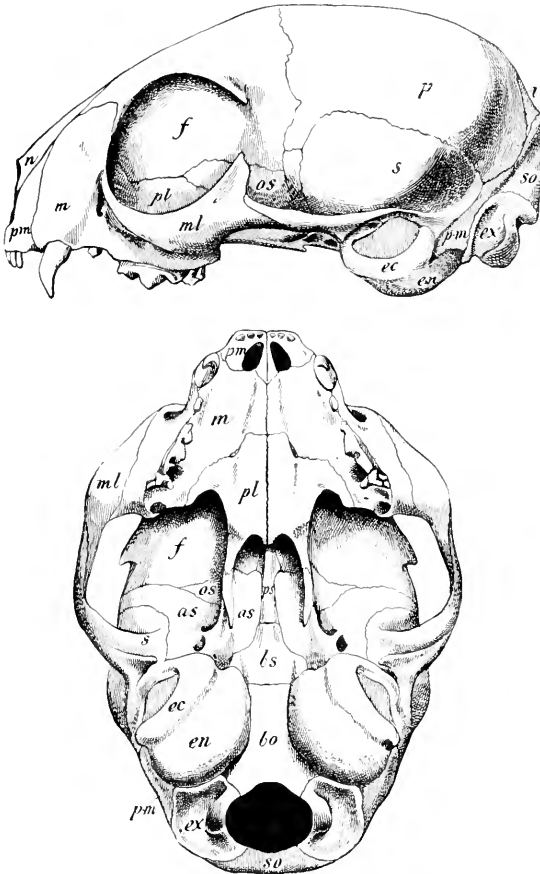
The oblique long diameter of the nasal cavity is the distance from the alveolar point to the point on the anterior convexity of the cribriform plate.

It is sometimes necessary to compare the length of the true base of the cranium with the length of the true base of the skull.

The base of the skull extends from the basion, on the anterior margin of the foramen magnum, to the alveolar point.

The base of the cranial cavity extends from the basion to the anterior edge of the anterior sphenoid. This diameter is termed the basi-cranial axis. It is impossible to fix accurately on the exterior of the

FIG. 408.



THE SKULL, NINETY DAYS AFTER BIRTH.

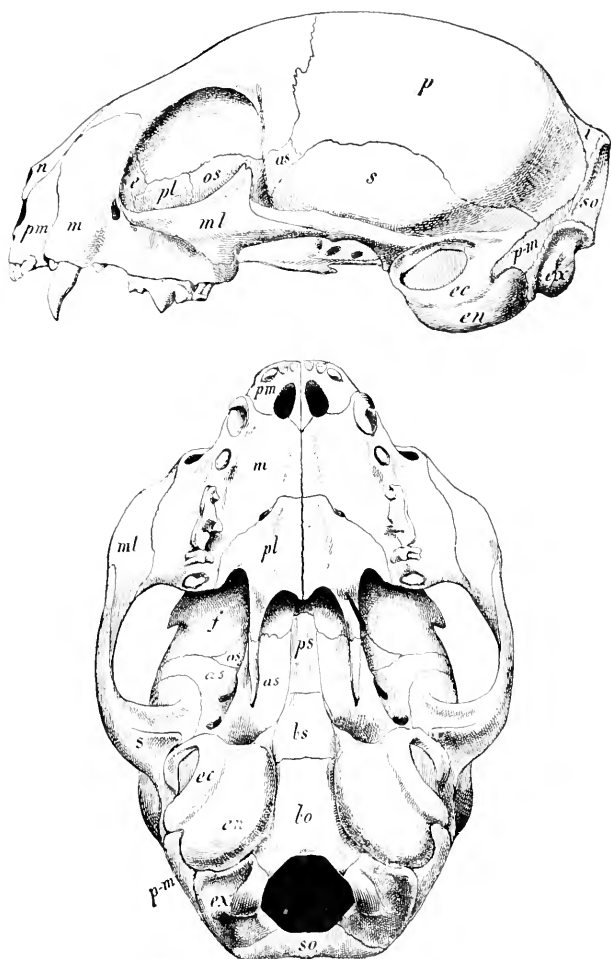
(Natural size.)

skull the anterior end of the cranial base; in adult skulls it is near the root of the palatine postnasal spine; in young skulls it is further forward, on a line joining the maxillary tuberosities.

The height of the cranial cavity is the intracranial vertical diameter of the skull from the bregma to the suture between the anterior and posterior sphenoids. In the young skulls the bones of the cranial

vault are joined together so loosely that when their muscular and fibrous coverings are removed they are usually pulled out of place; even the contraction of the sutural membranes in drying disturbs the actual shape of the skull. For these reasons the vertical diameters given in the table are approximate only.

FIG. 409.



THE SKULL,

ONE HUNDRED AND TWENTY DAYS AFTER BIRTH.

(Natural size.)

TABLE SHOWING THE GROWTH OF THE SKULL.

	Before birth.	At birth.	3 days.	7 days.	11 days.	15 days.	23 days.	30 days.	35 days.	44 days.	60 days.	70 days.	80 days.	86 days.	90 days.	120 days.	Adult.
From opisthion to alveolar point . . . . .	30	34	37	37	42	43	46	52	51	56	65	64	60	59	68	77	79
From opisthion to cribriform plate . . . . .	20	23.5	25	25	27	29.5	31	34	35	36	41	41	38	38	43	48	44
From opisthion to anterior point of cribriform plate . . . . .	24	27	30	30	32	35	35	40	40	44	49	49	46	40	52	55	54
From alveolar point to anterior point of cribriform plate . . . . .	9	12	12	12	14	14	14	17	16	19	22	22	23	20	24	30	33
From alveolar point to presphenoid . . . . .	11	14	14	14	15	15	17	20	19	20	27	25	25	23	27	32	38
From basion to alveolar point . . . . .	27	30	32	32	35	38	42	45	43	47	58	55	53	50	60	68	71
From basion to cribriform plate . . . . .	18	20	21	21	22	25	27	29	28	31	35	35	31	31	38	41	39
Width of mesethmoid . . . . .	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .	.5	2	2	2	3	5	4.5	6	5	6	10	. .
From cerebral basi-presphenoid suture to bregma . . . . .	15	. .	18	18	20	22	23	25	24	25	27	25	24	25	27	25	26
Cranial length index, <i>i.e.</i> , $\frac{\text{opisthion-cribriform length} \times 100}{\text{opisthion-alveolar length}}$ . . . . .	66.6	69.1	67.5	67.5	64	68.6	67.4	65.3	68.6	64.2	63	64	63.3	64.4	63.2	62.3	55.6
Cranial height index, <i>i.e.</i> , $\frac{\text{bregma-sphenoid height} \times 100}{\text{opisthion-cribriform length}}$ . . . . .	75	. .	72	72	74	74.5	74.1	73.5	77.4	69.4	65.8	60.9	63.1	65.7	62.7	52	59
Facial length index, <i>i.e.</i> , $\frac{\text{alveolar-cribriform length} \times 100}{\text{opisthion-alveolar length}}$ . . . . .	30	35.2	32.4	32.4	33	32.5	30.4	32.6	31.3	33.9	33.8	34.3	38.3	33.8	35.2	38.9	40.5

\*



## VARIATIONS IN THE SKULL.

The size and shape of the adult skull can be obtained by straight measurements, curved measurements, angular measurements, and measurements of capacity.

(1.) Straight measurements are made by taking the shortest distance between two points. When these points are upon the same aspect of the skull, straight compasses can be used; if, however, they lie on different aspects, curved calipers or sliding calipers, graduated in millimetres, must be employed.

(2.) Curved measurements are taken with a small metal tape-measure applied directly to the surface and made to follow its undulations. The horizontal and vertical transverse circumferences of the skull are sometimes measured in this way.

(3.) Angular measurements may be taken directly with the instrument known as a protractor, or the angle may be fixed by compasses and then measured on the protractor. Compasses of different sizes and shapes can be easily made by joining two narrow strips of cardboard at one end by a metal eyelet. If the skull has been bisected, some of the angles can be traced upon transparent paper. In this way can be determined the angle which the plane of the foramen magnum forms with the cranial base, the inclination of the vertical plate of the occipital or of the front of the face, and the angle formed at the anterior end of the anterior sphenoid by lines drawn from the basion and the premaxillary alveolar point.

(4.) The capacity of the cranial or nasal cavity can be obtained by measuring in a graduated glass the amount of fine shot it takes to fill it. Before filling the cavity the larger foramina must be closed.

In the following table I have given only straight measurements and such as are not difficult to obtain. They cover the length, breadth, and height of the entire skull, taken in different regions and between different points; also the diameters of the nasal, orbital, zygomatic, and auditory openings; the length of the parts of the alveolar borders, the diameters of the hard palate, and the distance between fixed points on the cranium and the face. From the data here presented almost any index can be constructed. For example: if we wish to know the breadth of the skull in terms of the length, it can be obtained from the breadth index, or  $\frac{\text{maximum intertemporal width} \times 100}{\text{premaxillary-inion length}}$ .

VARIATIONS IN THE SIZE OF THE SKULL.

	MALE.												FEMALE.												
	100	99	95	93	91	91	91	90	88	80	76	94	92.5	92.5	92	91	90	88	86	85.5	84.5	83	82	81	79
Premaxillary point toinion . . . . .	85	86	80	82	81	80	79	79	79	68	67	82	81	78	78	80	78.5	75	74	76	75.5	72	73	71	68
Basal length from premaxillary point to basion . . . . .	22	24	22	24	24	22	23	21	20.5	20	20	24	24	23	24	22	22	21	21	23	22	21	21	21	19
From basion to line of postglenoid processes . . . . .	30	30	28	29	29	28	28	27.5	29	25.5	25	24	29	27	28	29	29	27	26	28.5	28	27	26	26	24
From basion to line of posterior edge of roots of hamular processes . . . . .	13.5	12.5	10	12	11	10	12	12	11.5	10.5	10	13	12	12	11	12	11	12	10	11	12	10	11	9.5	12
From anterior edge of premaxillaries to posterior end of their palate processes . . . . .	24	22	21	22	21	21	22	21.5	20	17	18	21	20	20	21	21.5	20.5	19	19	20	20	19	20	19	18
From anterior edge of premaxillaries to transverse palatine suture . . . . .	42	40.5	39	39	39.5	37	37	38.5	35	33	32	38	37	37	37	36.5	36	36	35	36	36	33	34.5	34	33
From anterior edge of premaxillaries to tip of post-nasal spine . . . . .	41	41.5	40	41	40.5	37	38	40	40	34	34	41	41	39	38	41	40	39	37	39	36	35	36	35.5	35
From tip of postglenoid process to posterior edge of infraorbital foramen . . . . .	24	25	23	24	24	23	21	24	24	18.5	19	24	23	21	20	23.5	22.5	23	20	21	21	20	21	19	19
From tip of postglenoid process to tip of maxillary tuberosity . . . . .	5	5	5	5	5	5	6	6	5	5	5	6	5	6	5	5	6	4	5	5	5	5	6	5	5
From interpremaxillary suture to outer edge of alveolus for lateral incisor . . . . .	11	11	10	10	9	9	8.5	10	10	8.5	8	9	10	8	9	9	8	9	9	8	9.5	8.5	8	8	8.5
From outer edge of alveolus for lateral incisor to posterior edge of alveolus for canine . . . . .	3	3	3	4	2	4	3	3		2	2	3	3	4	4	3.5	4	3	3	3	1.5		2	3	2
From posterior edge of alveolus for canine to anterior edge of alveolus for first premolar . . . . .	24	23	23	23	23	25	23	23	21	21	22	23	21	22	24	24	23	22	22	22	23	24	20	21	20
From posterior edge of alveolus for canine to posterior edge of alveolus for third premolar . . . . .	21.5	21	21	22	21	21	20	20	19	18.5	20	20	22	21	21	21	21	20	20	20	20.5	18	19	17.5	19
From lowest point on paracipital process on longitudinal line to anterior end of bulla . . . . .	15	18.5		22	13	14	16		15	11		7	15	18	14	12	15	16	13	16	14	12	12.5	11.5	13
Frominion to anterior end of interparietal . . . . .	48.5	51	43	44	43	45	45	44	42.5	41	39	45	44.5	45	43	42	44	44	43	40	40	39	38	38.5	40
Frominion to bregma . . . . .	78	77	72	72	68	67	72	71	66	62	59	72	69	63	61	70.5	69	71	64	67	64	63	64.5	62.5	61.5
Frominion to nasion . . . . .	23	25	22	21	25	20	20	20	22	20	20	23.5	26	21	22	20.5	22	19	21	21	21	18	20	16	17.5
Median length of nasal bones . . . . .																									
Height of nasal aperture, from upper boundary to ridge of alveolar premaxillary tubercle . . . . .	12	12	10	12	13	13	12.5	11.5	12	11	9	11	11	10	11	11.5	11	10	10	9.5	11	10	9	9	10
From premaxillary alveoli to median lowest edge of nasals . . . . .	17	16	15	15	15	14	15.5	15	16	11.5	12	14	13	14	16	15.5	15	14	13	14	13.5	12	12	13.5	
From posterior edge of premaxillary alveoli to tip of postnasal spine . . . . .	41	39	37	37	37	35	34	36	33	30	29	35	35	35	34	35	34	33	33	34	34	31	31.5	32	31
Width of palate between outer edges of lateral incisors . . . . .	9	9	10	11	10	10	13	10	9	9	10	12	12	11	10	9.5	12	9	10	12	10	10	11	9	10
Width of palate between inner edges of canines . . . . .	17	15	14	14.5	14	13	15	15	15	12	12	15.5	14	16	14	15	15	12	15	15	13	14	14	12	13.5

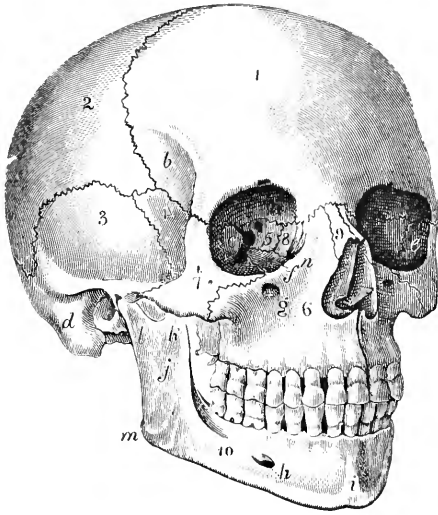
Width of palate between anterior end of inner edges of second premolars . . . . .	25	24	22	22.5	22	20	23.5	23	21	19	18	23.5	22	22	20	23	22	21	21	21	18	21	20.5	20
Width of palate between posterior edges of third pre-molars . . . . .	41	38	38	36	37	37	39	38	36	34	34	39	35	38	36	36	36	36	36	36	35	35	34	35
Width of pterygoid fossa at pterygo-palatine suture . . . . .	16	15	13	13	15	12.5	13	12	11.5	11	10	13	11	14	12	13	14	12	14	13	10.5	13	12	11.5
From external pterygoid process to zygoma parallel with glenoid fossa . . . . .	25	26	25	23	22.5	22	26	24	25	18	18	25	23	25	22	21	25	22	23	22	20	21	21.5	19
From squamos-sphenoid suture at anterior inner end of glenoid to middle of palato-maxillary notch . . . . .	25	25.5	24	25	25	22	21	24	25	20.5	20	26	25	23	24	23.5	24	24	21	19.5	22	21	20	20
Maximum zygomatic width of skull . . . . .	69	69.5	68.5	64	65	62	69	67.5	64	55	55	69	63.5	68	64	63	66	63	63	62.5	60	60	56	57
Width between inner edges of postglenoid processes . . . . .	31	34	32	32	35	33	32	31.5	34	32	33	36	32	34	31	33	34	35	31	31.5	33	30	31	28
Maximum mastoid width . . . . .	42	43	40.5	41	41	39	41	39.5	40	37	38.5	42	41	42	40	41	42	40	39.5	38	37	39	38	37.5
Spread of condyles . . . . .	20	21.5	21	21	22.5	21	20	21	20.5	20.5	21	21	22	21	22	21.5	21.5	22	21	21	20	21	19	19.5
Maximum intertemporal width . . . . .	42	43	40	42	41	41	42	41	38	41	41	41.5	40	42.5	42	42	42	42	42	40	39	41	40	39
Width just behind frontal postorbital processes . . . . .	31	30	27	30	29	31	31	28	32	32	32	28	30	30	30	26	29	33	29	28	29.5	27	29.5	31
Distance between staphylions . . . . .	12	12.5	10	9	11	12	7	6	14			4	10	15	13	10	14	15	9.5	19	14	11	18	18
Width between frontal postorbital processes . . . . .	56	54	45	49	44.5	44.5	50.5	44.5	43.5	41	41	50	47	54	52	48	50	46	45	42	44	43	41.5	42
Minimum width about on level with upper end of nasals . . . . .	22	20.5	18	18	16	16	20	17	17	15	16	19	18	19	18	18	19	18	18	16	16	16	15.5	16
Width between inner edges of infraorbital foramina . . . . .	31	28	27	28	25	25	28	28	25	23	22	26	25	27	27	27	26	24	27	25	24	25	22	25
Width between outer edges of canine eminences . . . . .	29	25	24	23.5	27	22	26	24	24	21	20	25	23	26.5	22	24	24	22	24	23.5	22	21.5	21.5	20
Orbital width; lachrymal tubercle to tip of malar post-orbital process . . . . .	28.5	28	26	26	25	25	25	25	27	24	25	26	27	27	28	29.5	26	25	25	25.5	25	24	24	26
Orbital height, maximum, at right angles to above . . . . .	25	25	25	22	23	24	23.5	24	23.5	24	21	21	23	24	23	24.5	23.5	25	23	23	23	23	25	24.5
Nasal aperture; width just below angles of nasals . . . . .	12	13	12	12	12	11.5	12	12	12	11	10	12	12	12	11	13	12	10	12	11.5	12	10.5	11	10
External auditory meatus, longest diameter, oblique from behind downward and forward . . . . .	8	8	8	8	8	7	7.5	8	8	8	7	8	7	8	8	8	7	9	8	8	7	6	8	
External auditory meatus, diameter transverse to above . . . . .	5	4.5	5	5	5	4	4.5	4.5	5	5	4	5	5	5	5	4.5	4.5	4	5	5	4	4.5	5	
From middle of outer edge of alveolus of canine to tip of nasal process of maxillary . . . . .	37	32.5	31	31	30	28	32	31	29	26	25	30	26	31	33	30	31	28	29	30	28	27	26.5	24.5
Width of temporal fossa at roots of postorbital pro-cesses . . . . .	21	22	20.5	20	20	17	20	19	20	15	15	21	21	20	21	20	21	18	18.5	19	18	19	16	16.5
From malar postorbital process to union . . . . .	39	61	58	56	55	58	56	56	50	49	49	58	57	57	56.5	55	55	60	53	53	51.5	50	49	
Height of skull from base to bregma . . . . .	33	35	35	32	30	32	32	31	29	30	32	33	31	32	32	32	32.5	32	31	30.5	30	31	30	30
Height of skull from nasion to middle of transverse palatine suture . . . . .	31	29	26	27	26	25	26	27	25	22	20	28	27	24	25	26	28	25	25	25.5	25.5	25	25	22.5
Height of skull from basion to union . . . . .	29	28	26	26.5	26	24	25	25	23.5	22	21	26	25	24	25.5	24.5	26	25	25	24	24	22	26	22
Height of skull; maximum including bulla . . . . .	43	43	43	42.5	40	45	43	42	40	42	42	43	41	42.5	40	42	42	45	41	40	40	38	40	39

## HUMAN SKULL.

## FRONT ASPECT.

If the skull of man and the skull of the cat be placed side by side, with the anterior ends directly in front of the student, the following general differences between them can be readily observed:

FIG. 410.



THE SKULL, SEEN PARTLY IN FRONT AND ON THE RIGHT SIDE.

1, frontal bone; 2, parietal bone; 3, temporal bone, squamous portion; 4, sphenoid bone, temporal surface of its great wing; 5, ethmoid bone, orbital surface; 6, maxilla; 7, malar bone; 8, lachrymal bone; 9, nasal bone; 10, mandible; *a*, orbital plate of the frontal bone; *b*, temporal surface; *c*, orbital surface of the large wing of the sphenoid bone; *d*, mastoid portion of the temporal bone; *e*, orbital surface of the malar bone; *f*, orbital plate of the maxillary; *g*, infraorbital foramen; *h*, mental foramen; *i*, symphysis; *j*, ramus; *k*, coronoid process; *l*, condyloid process; *m*, angle; *n*, lachrymal fossa.

far below the level of the malar bones and is separated from them by conspicuous notches.

In the cat, the alveolar border is V-shaped, does not project downward, and is near the lower margins of the nasal and orbital openings.

In man, the nasal bones project prominently forward above the nasal aperture, which is narrow above and wide below.

In the cat, the nasal bones are flattened and the nasal aperture is wide above and narrow below.

In man, the orbits are relatively small and close together; each orbit is shut off from the temporal fossa by a bony wall, formed by processes from the frontal, sphenoid, and malar bones.

In the cat, the orbits are large, more widely separated, and face

In man's skull, the anterior outline is vertically oval; the forehead is high, broad, and almost vertical; the face below and between the orbits is flat, and the lower part of the median symphysis of the lower jaw projects anterior to the teeth.

In the cat's skull, the outline is transversely oval; the forehead is narrow and slopes rapidly backward; the face anterior to the orbits is prolonged forward, and the chin retreats so far that its mental point is under a line joining the small first upper premolar teeth.

In man, the alveolar parts of the maxillary bones form a curved process which projects downward

outward as well as forward; they communicate freely with the temporal and zygomatic fossæ.

The anterior aspect of the human skull should now be examined in detail.

Its outline is formed by the frontal above and the parietals, temporals, and malars at the sides. On the forehead are the **frontal eminences** and **superciliary ridges**, on the median line above the naso-frontal suture is the flattened **glabella**.<sup>1</sup> The forehead is separated at the sides from the temporal fossæ by the **temporal ridges**, which begin at the frontal external angular processes. At the middle of the shortest transverse line connecting the temporal ridges is the point on the forehead known as the **ophryon**.<sup>2</sup> Each orbit is a pyramidal cavity with a quadrilateral base, bounded by the frontal, maxillary, and malar bones; on the superior margin is the **supraorbital notch**. The **floor** is formed by the orbital plates of the maxillary and palatine bones; the **outer wall** by the malar and the orbital surface of the great wing of the sphenoid; the **roof** by the orbital plate of the frontal and the orbital surface of the small wing of the sphenoid; the **inner wall** by the maxillary, the lachrymal, the os planum of the ethmoid, and part of the body of the sphenoid. At the apex of the orbit is the round **optic foramen**, lateral to which and partially separating the roof from the outer wall is the elongated **sphenoidal** or **superior orbital fissure**. Separating the floor from the outer wall is the longer **spheno-maxillary** or **inferior orbital fissure**. At the junction of the roof and the inner wall are the two **ethmoidal foramina**; at the inner lower angle are the **lachrymal groove** and **foramen**. The **transverse suture** joins the frontal to the malar, sphenoid, ethmoid, lachrymal, and maxillary, and is continued medially above the nasal bones; the different parts of the transverse suture, therefore, are known as the fronto-malar, fronto-sphenoidal, fronto-ethmoidal, fronto-lachrymal, fronto-maxillary, and naso-frontal sutures; on the inner wall are the maxillo-lachrymal, ethmo-lachrymal, spheno-ethmoidal, and spheno-palatine sutures. On the floor at the inner side are the maxillo-lachrymal, maxillo-ethmoidal, ethmo-palatine, and maxillo-palatine sutures; at the outer side is the malar-maxillary suture. On the outer wall is the spheno-malar suture.

On each side of the face under the orbit is the **infraorbital foramen**,

<sup>1</sup> Diminutive of *glaber*, smooth.

<sup>2</sup> From (Gr.) *ophrus*, eyebrow.

lateral to which is the malo-maxillary suture joining the prominent malar to the depressed maxillary. The pyriform nasal aperture is divided vertically by the anterior edge of the nasal septum, formed by the mesethmoid above and the vomer below. At the side of each nasal cavity may be seen the maxillo-turbinal, separating the inferior and middle meatuses; further back and higher up is the middle turbinated bone.

#### UPPER ASPECT.

When the human skull is viewed from above its outline is oval, because it is the outline of the vault of the cranium; the only parts of the face which are visible are the ends of the nasal bones and in some specimens the edges of the zygomatic arches. The superior aspect of the cat's skull exhibits the face as well as the cranial vault. The outline in man is formed of the frontal, the parietals, and the upper, or interparietal, portion of the occipital bone. The frontal is joined to the parietals by the transverse coronal suture; the sagittal suture runs backward from the bregma, at the middle point of the coronal suture, to the lambda, at the middle of the transverse occipito-parietal or lambdoidal suture. In some skulls the sagittal suture is retained between the two frontal bones; this portion is termed the metopic suture; it usually persists in the adult as a fissure in the frontal bone just below the glabella. The parietal bones exhibit the parietal eminences, and, near the sagittal suture behind, the parietal foramina, marking the obelion, the point at which the sagittal suture begins to disappear with advancing age.

#### POSTERIOR ASPECT.

The posterior aspect of the human skull presents, at the lower part, that portion of the occipital bone situated above the external occipital protuberance, and, at the upper part, the two parietals; at the sides are the squamosals.

Its outline is almost circular, but flattened somewhat at the inferior margin along the superior curved line. Below, far in advance, is seen the posterior aspect of the lower jaw. Near each lower outer corner is the asterion, a point where the lambdoidal, occipito-mastoid, and parieto-mastoid sutures meet. On the greatest posterior projection of the occipital bone is the occipital point. The external occipital protuberance marks the inion.

## LOWER ASPECT.

The human skull should now be inverted and the lower jaw removed to expose the base (Fig. 411); the skull of the cat should be placed in the same position beside it for comparison. It will be noticed that the general outline of man's skull is almost circular, and that the centre of the circle falls at the basion, on the anterior margin of the foramen magnum.

The outline of the cat's skull is oblong, and the centre of the long diameter is in the middle pterygoid fossa, just behind the sutures between the pterygoids and the palatines.

In man, the zygomatic arches are relatively small and anterior.

In the cat, the arches are relatively large and near the middle of the lateral outline.

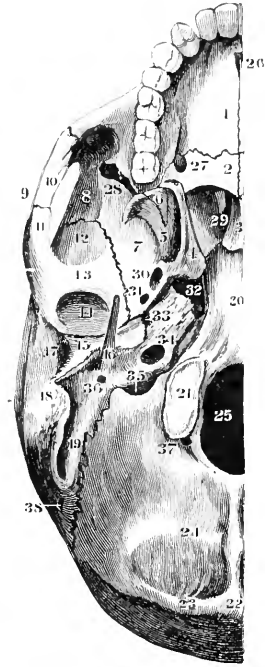
In man, the alveolar border and hard palate are on a higher level (in this position of the skull) than the rest of the base, which slopes from the mastoid processes sharply downward and forward.

In the cat, the alveolar border and hard palate are raised but little above the rest of the base, which, aside from the irregularity due to the auditory bullæ, is measurably flat.

When man's skull is viewed from below, the forehead, orbital rims, and nasal bones are visible at the anterior end, and, owing to the anterior position of the foramen magnum, the greater part of the supraoccipital is visible at the posterior end.

The greater growth of the human brain, and especially of the

FIG. 411.



EXTERNAL VIEW OF THE BASE OF THE SKULL. RIGHT SIDE.

1, palatine plate of the maxillary; 2, palatine plate of the palatine bone; 3, vomer; 4, 5, internal and external pterygoid plates; 6, pyramidal process of the palatine bone; 5, 6, occupy the pterygoid fossa; 7, under part of the great wing of the sphenoid bone, forming part of the zygomatic fossa; 8, temporal surface of the great wing of the sphenoid bone; 9, zygoma; 10, zygomatic process of the malar bone; 11, zygomatic process of the temporal bone; 12, squamous portion of the temporal bone; 13, articular eminence; 14, glenoid fossa; 15, tympanic plate; 16, styloid process; 17, auditory meatus; 18, mastoid process; 19, digastric fossa; 20, conjunction of the basilar process and body of the sphenoid bone; 21, occipital condyle; 22, occipital protuberance, and crest leading from it downward; 23, 24, superior and inferior semicircular lines; 25, occipital foramen; 26, anterior palatine fossa; 27, posterior palatine foramen; 28, sphenomaxillary fissure; 29, posterior naris; 30, foramen ovale; 31, foramen spinosum; 32, lacerated foramen; 33, Eustachian tube; 34, entrance of the carotid canal; 35, jugular foramen; 36, stylo-mastoid foramen; 37, pit with a posterior condyloid foramen; 38, mastoid foramen.

anterior cerebral part, has pushed the cranium over the face, which thus appears to depend from its anterior end; the assumption of the upright posture has brought the foramen magnum almost in the centre of the cranial base.

None of these features are visible in the cat's skull.

The student should now examine the base of the human skull in detail.

At the extreme anterior end is the arcuate **alveolar border**, with its sixteen **teeth**; it ends behind at the **maxillary tuberosities**. Behind its middle point, in front, is the single **anterior palatine fossa**, from which the **mesopalatine suture** is continued backward to the **post-nasal spine**. The **transverse palatine suture** unites the palatine processes of the maxillary and palatine bones. Near each outer posterior corner is the **posterior palatine foramen**; just behind it are several accessory palatine foramina.

Posterior to these foramina is the **hamular process** of the inner pterygoid plate; between this process and the flaring outer pterygoid plate is the small **pyramidal process** of the palatine bone, forming the lower part of the **pterygoid fossa**, which ends above where the two plates come together.

By tilting the skull slightly the student can look through the posterior nares into the nasal chamber and examine the median partition, the **vomer**, and the superior, middle, and inferior turbinated bones, with the corresponding meatuses. On the roof of each nasal fossa are the openings in the cribriform plate and the entrance to the sphenoidal sinus; on the outer wall are the spheno-palatine foramen, the opening of the antrum, and the end of the lachrymal canal.

Each **posterior naris** is bounded below by the palatine bones (above in this position of the skull), medially by the vomer, laterally by the inner pterygoid plate, and above by the under surface of the body of the sphenoid, the vaginal process of the inner pterygoid plate, the ala of the vomer, and part of the sphenoidal process of the palatine bone. Between the vaginal process and the vomer is the **basipharyngeal canal**; between the vaginal process and the sphenoidal process of the palatine is the **pharyngeal** or **pterygo-palatine canal** for the pterygo-palatine nerves. On each side above the pterygoid fossa is a shallow **scaphoid fossa** for the tensor tympani muscle; it is pierced by inconstant foramina.



Behind the scaphoid fossa is the irregular opening known as the **middle lacerated foramen**. It is bounded medially by the basisphenoid and basioccipital, in front and laterally by the sloping **spheno-petrosal lamina** of the alisphenoid, and behind and medially by the apex of the petrous part of the temporal, in which can be seen the anterior end of the **carotid canal**. Projecting into the anterior medial corner of the lacerated foramen is the **vaginal tubercle**, just below the posterior opening of the **Vidian canal**. Above this opening the **lingula** of the sphenoid is sometimes visible.

In front of the spheno-petrosal lamina is the **foramen ovale**, behind and lateral to which are the smaller **foramen spinosum** and the prominent **angular spine**. The flattened surface of the sphenoid in front of these foramina is the zygomatic surface of the great wing; it ends in front at the **sphenoidal fissure**, or **anterior lacerated foramen**, and is separated from the temporal surface of the wing by the **infratemporal crest**, and from the triangular zygomatic surface of the squamous by part of the squamo-sphenoidal suture.

Behind this surface of the squamous is the deep, oval **glenoid cavity** for the condyle of the lower jaw. It is bounded in front by the **articular eminence**, and behind by the **Glaserian fissure**, which separates the petrous and squamous from the **tympanic plate**. The medial edge of the tympanic plate is the **vaginal process**; its posterior end forms a sheath around the base of the **styloid process**. The lateral edge, known as the **auditory process**, is the lower margin of the external auditory meatus. Behind the styloid process is the **stylo-mastoid foramen** for the facial nerve. The irregular suture between the tympanic plate and the mastoid is the **auricular fissure**, giving exit to Arnold's nerve.

The **mastoid process** is very prominent; the groove medial to it is the **digastric fossa**. Near its upper end is the **mastoid foramen**, and to its medial side is the furrow for the occipital artery.

The median part of the base of the cranium, anterior to the foramen magnum, is formed of the basioccipital; it exhibits on the middle line the variable **pharyngeal tubercle**.

On either side of the foramen magnum is a flattened **occipital condyle**. Above the condyle is the anterior opening of the **anterior condyloid canal**, and behind it, in a fossa, the posterior opening of the inconstant **posterior condyloid canal**.

Between the styloid process and the basioccipital is the large posterior lacerated or jugular foramen, the outer wall of which is pierced by the auricular canaliculus for Arnold's nerve. The foramen is divided into two parts by the jugular spine projecting medially from the upper part of the outer wall. The anterior division is for the ninth, tenth, and eleventh cranial nerves; the posterior, for the beginning of the jugular vein. In front of the lacerated foramen and medial to the tympanic plate is the posterior opening of the carotid canal. In the crest behind the carotid canal is the opening of the tympanic canaliculus for Jacobson's nerve, medial to which is the petrous fossula and the opening of the aquæductus cochleæ. On the posterior wall of the carotid canal are the openings of the carotico-tympanic canaliculi. Anterior and medial to the carotid canal is the apex of the petrous, extending forward to the middle lacerated foramen; directly anterior to the canal is the Eustachian opening.

Behind the foramen magnum, on the supraoccipital, is the median external occipital crest, ending behind in the external occipital protuberance. The ridges curving outward and forward from the crest are the inferior and superior curved lines.

#### LATERAL ASPECT.

The lateral aspect of the human skull shows clearly the globular shape of the cranium and the inferior position of the bones of the face. In the cat's skull the cranium is long and low, and the face is prolonged forward.

The outline of the lateral aspect of the human skull is irregular. It exhibits the following points, beginning at the top and passing forward: the bregma at the vertex, the glabella at the forehead, the nasion at the root of the nose, the prominent nasal bones, the emargination of the nasal aperture, the nasal spine, at the base of which is the nasal point, the maxillary alveolar border and alveolar point, the teeth, the mental point on the chin, the horizontal line of the body of the mandible, its rounded angle, the almost vertical edge of the ramus of the mandible, the condyle, the tympanic plate of the temporal, the prominent mastoid process, the outline of the basal part of the occipital, the inion on the occipital protuberance, the occipital point marking the greatest convexity of the occipital bone, the lambda, the depression at the obelion, the bregma.

The zygomatic arch is shorter and closer to the side of the cranium than it is in the cat. It defines externally the temporal fossa above from the zygomatic fossa below.

The **temporal fossa** is easily recognized. It is separated from the orbit in front by a bony wall; it communicates by an oval aperture with the zygomatic fossa situated below it and extending medially under the cranium; it is open above.

The temporal fossa is bounded above and behind by the **temporal line**, which begins at the frontal external angular process, crosses the coronal suture at the **stephanion**, and curves backward and downward on the parietal to the **asterion**. A second curved line somewhat below the temporal line begins at the front of the parietal, and arches to the notch at the lower end of the parieto-mastoid suture, whence it is continued forward as the **posterior root of the zygoma**; this line marks the attachment of the temporal muscle.

The temporal fossa is bounded below by a plane passing almost horizontally through the upper edge of the zygomatic arch and the **infratemporal crest** on the great wing of the sphenoid and the squamous of the temporal.

Its anterior wall is formed of the temporal surfaces of the frontal external angular process, of the great wing of the sphenoid, and of the orbital process of the malar.

Its inner and posterior walls are formed by the squamous, the parietal, the great wing of the sphenoid, and the frontal. On the inner wall are the following sutures: the squamous suture, joining the temporal and the parietal, the coronal suture, and its continuation the fronto-sphenoidal suture, and at the **pterion** the short transverse sphenoparietal suture.

The roof of the **zygomatic fossa** is formed medially of the zygomatic surfaces of the squamous and the great wing of the sphenoid; laterally it presents an aperture which is bounded externally by the zygoma and leads upward into the temporal fossa. The tip of the coronoid process of the mandible projects into this aperture.

The inner wall, which is complete only in the anterior part, is formed by the lateral surface of the outer pterygoid plate and the zygomatic surface of the maxillary. The anterior wall is formed by the maxillary and the malar. The outer wall is furnished by the zygoma above and the ramus of the mandible below.

On the inner wall, at the upper anterior part, between the pterygoid plate and the maxillary, is the vertical **pterygo-maxillary fissure** leading into the **spheno-maxillary fossa**. From the top of this fissure the **spheno-maxillary** or **inferior orbital fissure** passes forward and outward between the spheno-maxillary crest on the sphenoid and the tuberosity of the maxillary; it represents the wide aperture of communication seen in the cat between the zygomatic fossa and the orbit. On the roof of the zygomatic fossa is the oblique squamo-sphenoidal suture, and on the outer wall the **malo-temporal** or **zygomatic suture**.

The **spheno-maxillary fossa** cannot be clearly seen from the exterior. Its inner wall is formed by the vertical plate of the palatine and is pierced by the **spheno-palatine foramen**. The pterygoid process limits it behind, and exhibits the **foramen rotundum** and the anterior openings of the **Vidian** and **pharyngeal**, or **pterygo-palatine, canals**. Its roof is the under surface of the great wing of the sphenoid. A small portion of the zygomatic surface of the maxillary and the orbital (ethmoidal) process of the palatine limit it in front. It is wide above and narrow below, where it ends in the **posterior palatine canal**. (See page 332.)

On the lateral aspect of the skull, behind the zygoma, is the small **auditory meatus**, bounded below by the **tympanic plate**, above by the ridge known as the posterior root of the zygoma, and behind by the great **mastoid process**.

Above the temporal line in front is the **frontal eminence**, and near the line behind is the **parietal eminence**.

The exterior of the skull often presents, on the line of the sutures, small irregular bones which are not sufficiently constant to receive special names; they are known generally as **sutural** or **Wormian bones**, or **ossa triquetra**. They are found most frequently in the lambdoidal suture. A single bone occurring very often at the pterion is known as the **epipteric bone**.

#### THE CRANIAL CAVITY.

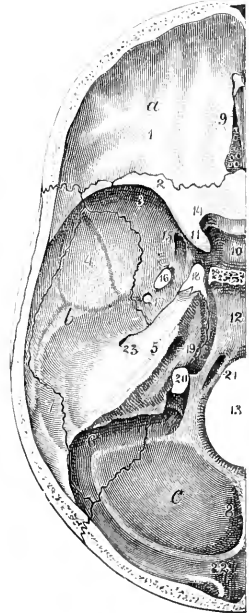
The interior of the human cranium is exposed by a transverse horizontal section through the ophryon and the occipital point. It is characterized by its globular form and by shortness of base, measured from the occipital foramen to the cribriform plate of the ethmoid. It differs from the cranial cavity of the cat in not possessing a bony tentorium, but especially in the greater size of the anterior and poste-

rior fossæ. The anterior fossa is sharply limited behind by the rounded posterior border of the small wings of the sphenoid; the middle fossa is limited behind by the superior border of the petrous portions of the temporal. The student should now identify the foramina and sutures seen on the external aspects of the skull and the relations between the outer and inner surfaces of the cranial bones. (Fig. 412.)

On the floor of the cavity in front, at the lower end of the median crest on the frontal bone, in the fronto-ethmoidal suture, is the small *foramen cæcum*, which in some specimens transmits a vein from the nose to the superior longitudinal sinus. Behind the foramen is the triangular ethmoidal *crista galli* for the attachment of the *falx cerebri*; on each side of this process is the perforated part of the *cribriform plate*, forming a shallow olfactory groove for the olfactory bulb of the brain. At the posterior end of each lateral fronto-ethmoidal suture is the *posterior ethmoidal foramen* for the posterior ethmoidal vessels; further forward is the *anterior ethmoidal foramen*, which transmits the anterior ethmoidal vessels, and also permits the nasal branch of the ophthalmic division of the fifth cranial nerve to pass from the orbit to the cranial cavity. The nerve then lies in a groove which leads from the foramen to a slit at the anterior end of the suture, through which it passes into the nasal cavity.

On each side of the olfactory groove the floor of the anterior cerebral fossa, formed by the orbital plate of the frontal bone, is marked by ridges, outlining grooves for the cerebral convolutions. Behind the *cribriform plate* are the *ethmoidal spine* and the level anterior part of the upper surface of the anterior

FIG. 412.



INTERNAL VIEW OF THE BASE OF THE CRANIUM. THE LEFT SIDE.

*a, b, c*, anterior, middle, and posterior cranial fossæ; 1, orbital plate of the frontal bone; 2, small wing of the sphenoid bone; 3, great wing of the same; 4, squamous portion of the temporal bone; 5, petrous portion of the same; 6, mastoid portion; 7, parietal bone; 8, occipital bone; 9, olfactory fossa and ethmoidal crest; 10, sella; 11, anterior clinoid process; 12, clivus; 13, occipital foramen; 14, optic foramen; 15, foramen rotundum; 16, foramen ovale; 17, foramen spinosum and groove from it, indicating the course of the great meningeal vessels; 18, middle lacerated foramen; 19, internal auditory meatus; 20, jugular foramen; 21, condyloid foramen; 22, commencement of the groove for the lateral sinus. The course of the groove is observed along the horizontal limb of the occipital cross, the postero-inferior angle of the parietal bone, the mastoid portion of the temporal, and the jugular process of the occipital, terminating at the jugular foramen.

sphenoid; a transverse ridge separates the latter surface from the **optic groove** for the optic chiasm, which terminates laterally at the **optic foramina**. Behind the groove is the **olivary eminence**, separated on each side from the **anterior clinoid process** by the notch for the carotid artery. The **sella turcica**, for the pituitary process of the brain, occupies the space between the olivary eminence in front and the square plate of bone, the **dorsum sellæ**, behind. It is bounded laterally by the **carotid groove**, which extends backward on the **lingula** of the sphenoid and ends in the **middle lacerated foramen**. Each superior angle of the dorsum sellæ is prolonged as a **posterior clinoid process**, beneath which the lateral margin is notched for the passage of the third cranial nerve. The sloping surface extending from the upper edge of the dorsum sellæ to the foramen magnum is called the **clivus**. Beneath the anterior clinoid process are the **sphenoidal fissure**, or anterior lacerated foramen, and the **foramen rotundum**; the former transmits the third, the fourth, the three branches of the ophthalmic division of the fifth, and the sixth nerve, some branches of the sympathetic plexus, the orbital branch of the middle meningeal artery, a recurrent branch of the lachrymal artery, and the ophthalmic vein. The foramen rotundum transmits the superior maxillary division of the fifth nerve. Further back and to the side is the large **foramen ovale**, for the inferior maxillary division of the fifth nerve, the small meningeal artery, and the small petrosal nerve. Lateral to the foramen ovale is the small **foramen spinosum**; it transmits the middle meningeal artery, which ascends forward in a groove on the squamous of the temporal. Behind these foramina, and separated from them by the **spheno-petrosal lamina**, is the middle lacerated foramen for the carotid artery, the Vidian nerve, and a branch from the pharyngeal artery.

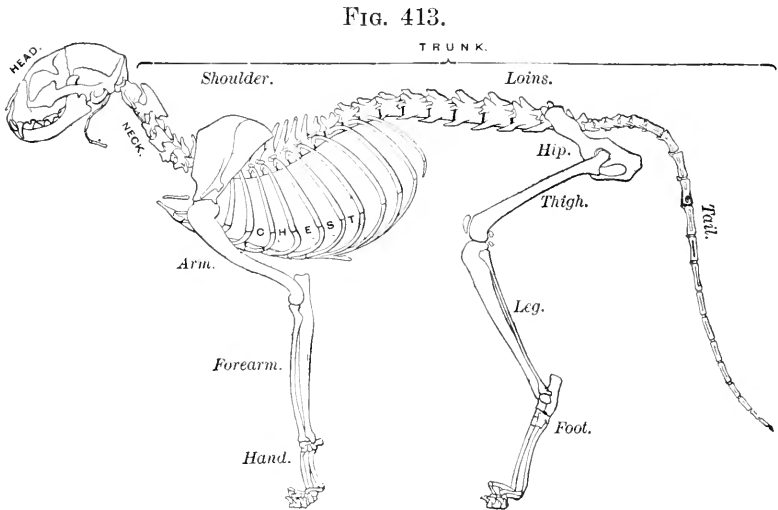
At the apex of the petrous in the lacerated foramen is the anterior opening of the **carotid canal**, and on the anterior surface is the **depression** for the Gasserian ganglion of the fifth nerve. Lateral to these features is the small **hiatus Fallopii** for the petrosal branch of the Vidian nerve and the petrosal branch of the middle meningeal artery. Anterior and lateral to the hiatus is the **opening** for the small superficial petrosal nerve, a branch of Jacobson's nerve from the tympanum. Behind these foramina is the **eminentia arcuata**, produced by the superior semicircular canal of the labyrinth. The thin roof of the

tympanum, the **tegmen tympani**, lies lateral to this eminence. The superior border of the petrous is grooved by the superior petrosal sinus, and the posterior border near the basioccipital by the inferior petrosal sinus. On the posterior surface of the petrous are the **internal auditory meatus**, the variable **floccular fossa**, and the opening of the **aquæductus vestibuli**.

On each side of the foramen magnum, in front, is the posterior opening of the **anterior condyloid canal** for the twelfth cranial nerve, and between the occipital and the petrous is the irregular **posterior lacerated** or **jugular foramen**, which transmits the ninth, tenth, and eleventh cranial nerves, the internal jugular vein, and the meningeal branch of the ascending pharyngeal artery. From the jugular foramen, the wide **groove** for the lateral sinus curves upward and backward on the temporal, the parietal, and the occipital bone; it meets the groove for the other lateral sinus and the vertical groove for the superior longitudinal sinus near the **internal occipital protuberance**. The **internal occipital crest** passes upward from the foramen magnum to the protuberance.

## CHAPTER VIII

## THE APPENDICULAR SKELETON—THE THORACIC LIMBS



THE REGIONS OF THE SKELETON.

The Appendicular Skeleton comprises the bony framework of the Anterior or Thoracic and the Posterior or Pelvic Limbs.

## THORACIC LIMBS.

Each Thoracic Limb consists of:

(1.) A proximal portion, the shoulder, which is supported by the shoulder girdle, an incomplete arch formed of the shoulder blade, or scapula, and the collar bone, or clavicle, and embedded in the muscles of the trunk;

(2.) A free portion, the part which alone is usually recognized as the limb. This portion is divided into:

- (a) The Arm, which is supported by a single bone, the **humerus**;
- (b) The Forearm, which has two long bones, the **radius** and the **ulna**, placed side by side;
- (c) The Hand, which is subdivided into:

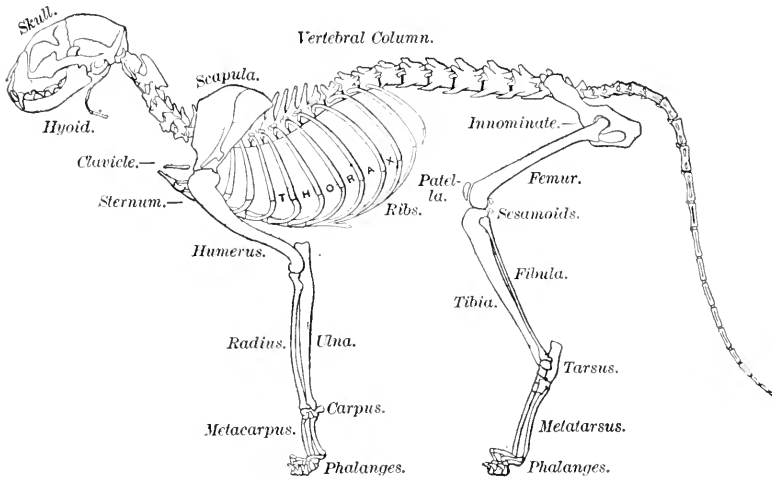
The Wrist, or **Carpus**, with eight short **carpal** bones;



The Palm, or Metacarpus, with five cylindrical **metacarpal** bones ;

The Fingers, or Digits, every one with two or three bones, the **phalanges**, arranged end to end.

FIG. 414.

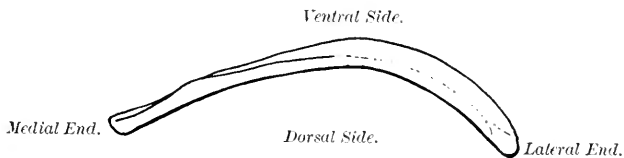


THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

### THE CLAVICLE.

**General Description.**—The Clavicle is a slender curved bone, from eighteen to twenty-five millimetres in length, embedded in muscle on the ventral side of the body in the interval between the point of the shoulder and the breast-bone. It is connected only by muscle and fascia with the thorax and the scapula, and has no proper ligaments of its own.

FIG. 415.



LEFT CLAVICLE. CAUDAL ASPECT.

It presents a broad, strongly curved **lateral end**, and a straighter, more cylindrical **medial end**. It has only two clearly defined surfaces, one cephalic, the other caudal, separated by dorsal and ventral borders.

The **ventral border** is arcuate; the point of maximum curvature lies in the outer third of the bone.

The **dorsal border** is emarginate.

The **cephalic surface** is flattened; it is narrower at the medial end than at the lateral end.

The **caudal surface** is more rounded, and is often marked near the medial end by a crest along the ventral border.

The medial end of the bone frequently has a distinct caudal direction.

**Nomenclature.**—Clavicle is from *clavicula*, [the diminutive of *clavis*, a key. Hyrtl<sup>1</sup> regards it as probable that *clavis* was also the name of a curved door-latch and with this meaning was applied to the collar-bone. *Clavis* is derived from the Greek *cleis*, *cleidos*, a key, whence *cleido-mastoid* for one of the clavicular muscles. The German word is *das Schlüsselbein*, the French, *la clavicule*.

**Determination.**—When the concave dorsal border is held uppermost and the curved end away from the student, the more rounded caudal surface and the inclination of the medial end will be on the side to which the bone belongs.

**Muscular Attachments.**—The **cephalo-humeral** muscle covers the clavicle and is firmly attached to its ventral aspect in the lateral half. The **cleido-mastoid** muscle is attached in the medial half.

**Ossification.**—The clavicle is said to be developed in membrane from a single centre of ossification.

### HUMAN CLAVICLE.

The clavicle in man is a relatively larger and much more important bone than it is in the cat. It articulates by movable joints with the acromion of the scapula and with the manubrium of the sternum, and hence attaches the upper limb to the skeleton of the trunk. By holding the shoulder-joint out from the body, while permitting freedom of motion, it enables the limb to accomplish most effectively a greater variety of movements.

When viewed from above or below, the clavicle has a sinuous curve; its medial two-thirds are bowed forward (ventrally) and its lateral third is bowed backward (dorsally). When viewed from in front or behind, its long axis is almost straight. For convenience of description the clavicle is divided into an outer (lateral) third and an inner (medial) two-thirds (Fig. 416).

The **outer third** is strongly compressed from above downward and

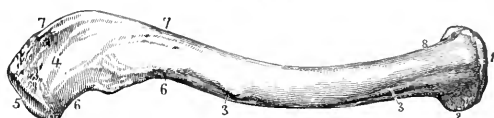
<sup>1</sup> Onomatologia Anatomica.

widened from before backward. It presents an emarginate **anterior border**, to which is attached the deltoid muscle; a middle prominence thereon is sometimes termed the **deltoid tubercle**. The wider arcuate **posterior border** is occupied by the trapezius muscle. It terminates medially in the large, roughened **conoid tuberosity** for the conoid part of the coraco-clavicular ligament. The terminal **lateral border** presents a flattened oval facet, which faces outward, downward, and forward, and articulates with the oval facet on the inner margin of the acromion of the

scapula. The **superior surface** is flat, roughened in front for the attachment of the deltoid, and roughened behind for the attachment of the trapezius; laterally a small portion is subcutaneous. The **inferior surface** is flat and crossed by an **oblique line** which passes from the conoid tubercle outward and forward to the anterior border and affords attachment to the trapezoid division of the coraco-clavicular ligament.

The part forming the inner two-thirds of the clavicle is prismatic or quadrilateral. At the outer end, where it is continuous with the outer part, it is narrower and prismatic; at the inner end it is swollen, especially behind (dorsally), and is almost cylindrical. It is by some authors described as having two surfaces, by others as having three surfaces, while others again distinguish four surfaces. Three surfaces, anterior, posterior, and inferior, are always distinct, separated by superior, anterior, and posterior borders. The sinuous **superior border** is the continuation inward of the anterior border of the outer part; it passes somewhat backward at the inner end, where it is elevated for the pectoralis major muscle. The **posterior border** begins laterally at the conoid tubercle and ends medially in the roughened triangular space on the posterior inferior aspect called the **rhomboid impression**, because to it is attached the costo-clavicular or rhomboid ligament. The **anterior border** is also the continuation inward of the anterior border of the flattened outer part. It is on the inferior aspect of the bone. Between the anterior and posterior borders is the **inferior**

FIG. 416.



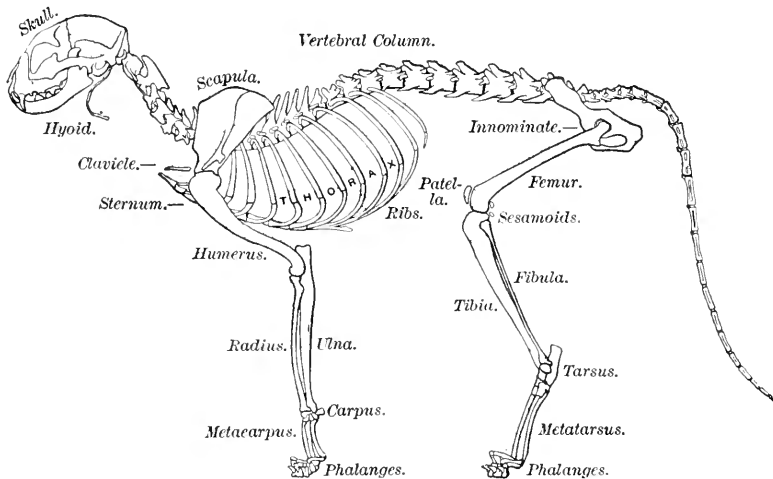
RIGHT CLAVICLE, UPPER VIEW.

1, sternal end; 2, portion which joins the cartilage of the first rib; 3, line of attachment of the pectoral muscle on anterior surface; 4, superior surface of the acromial end; 5, its articular surface; 6, anterior border, giving attachment to the deltoid muscle; 7, posterior border, giving attachment to the trapezius muscle; 8, superior border, position of origin of the sterno-mastoid muscle.

surface, wide laterally and medially, but narrower in the middle. Its outer part is concave and forms the **subclavian groove** for the subclavius muscle. On the inner part at the medial end, in front, is an oval facet for articulation with the cartilage of the first rib, and behind, the larger rough rhomboid impressions. The **posterior surface** is smooth and deeply concave from within outward. It is in relation with the brachial plexus of nerves and the subclavian vessels. To its inner part is attached the sterno-hyoid muscle. Near the middle is the chief nutrient foramen of the bone. The **anterior surface** is very wide at the inner end and narrow at the outer end. Its inner half or more is divided lengthwise by a strong **pectoral line**; the part above the line, sometimes called the superior surface, is more or less roughened behind for the attachment of the sterno-cleido-mastoid muscle; to the part below the line, sometimes called the anterior surface, is attached the pectoralis major muscle. The outer half of this surface is smooth and covered only by the platysma myoides muscle and the skin. The terminal **sternal surface** is occupied by an articular facet, which is convex from above downward and concave from before backward; it joins the clavicular facet on the superior margin of the manubrium of the sternum.

### THE SCAPULA.

FIG. 417.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

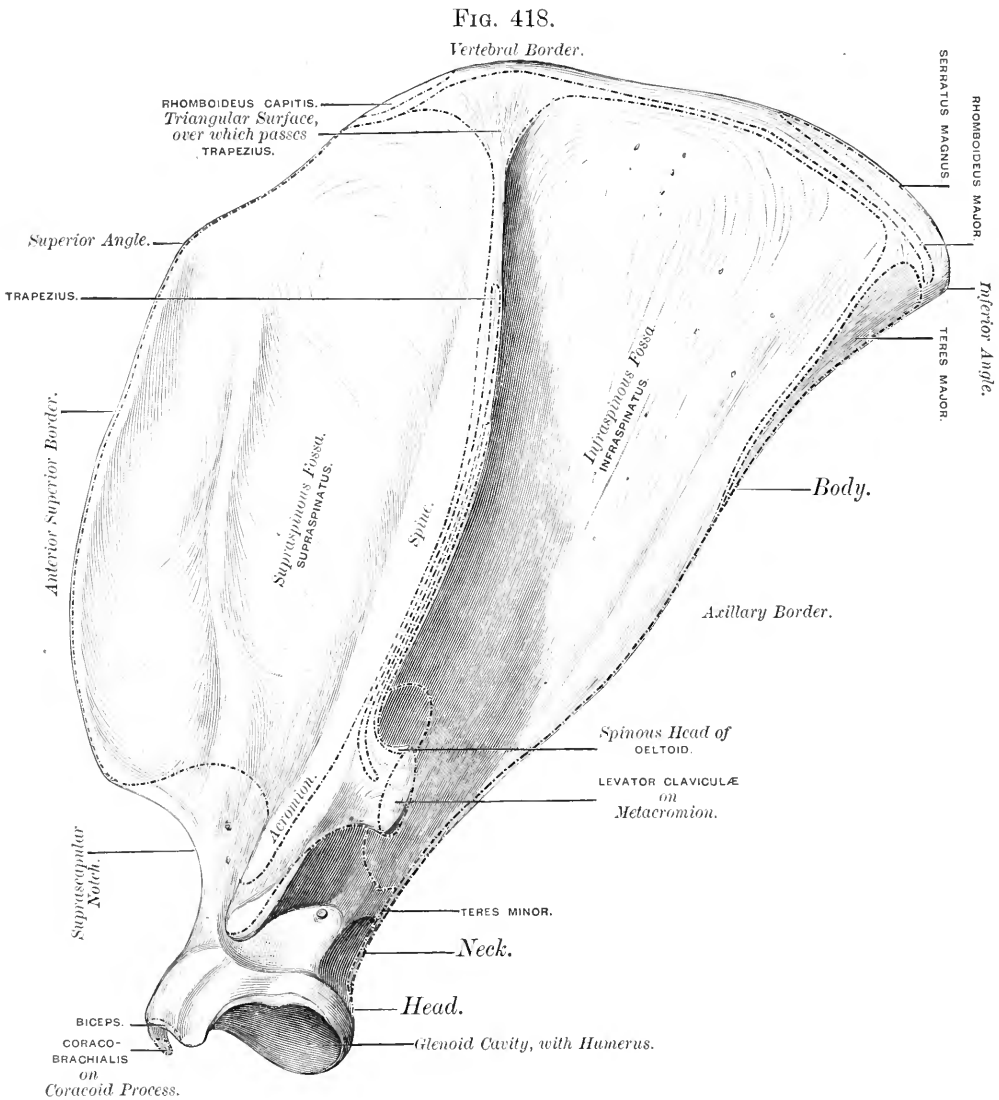
**General Description.**—The Scapulæ, the principal elements in the shoulder girdle, are large, flat bones lying on each side of the

anterior, or cervical, end of the thorax. Each scapula has a flat inner surface applied to the thorax and a keeled outer surface facing directly outward. The outline of the scapula is that of an elongated triangle, and it is so placed in the skeleton that the edge which forms the base of the triangle is above the level of the spinous processes of the thoracic vertebræ and faces upward and also slightly backward toward the tail; the shorter border is in front, the longer, straighter border behind; and the truncated lower angle, the apex, points downward and forward. The long axis of the triangle is, therefore, directed from above obliquely downward and forward. The outer surface of the scapula is well covered with muscles; it forms the prominent shoulder, and can be plainly seen, felt, and outlined through the skin. Except for the interposition of several layers of muscles, the inner surface is applied to the convexity formed by the anterior ribs. The scapula has an extended range of motion, and may assume very different positions in the various movements of the anterior extremities. This is due to the fact that it is but loosely joined to the axial skeleton. It is attached by muscles to the ribs, to the head, to the cervical and thoracic vertebræ, and by fascia, with the aid of the rudimentary clavicle, to the sternum. It articulates by the shoulder-joint with the bone of the arm, the humerus, with which and the bones of the forearm it is connected by many and important muscles. The scapula consists of a main upper portion, the body, separated by a constriction, the neck, from a very small lower and thicker portion, the head.

The **Body** is a thin translucent plate composed for the most part of two layers of compact bony tissue separated by a thin layer of cancellous tissue. It presents for examination two surfaces, three borders, and three angles.

The **outer surface** (Fig. 418) may be recognized as the surface supporting the high keel-like ridge. It is irregularly triangular, about one-third longer than wide. The upper edge, or base, is arcuate, and directed somewhat obliquely to the long axis of the surface, so that the anterior border is shorter than the posterior. The lower end is continuous with the neck, and is comparatively narrow, its width being less than a fourth of the greatest width. The greatest width is not at the upper border, but considerably below it. The outer surface is bounded above by the **vertebral border**, in front by the **anterior**

superior border, and behind by the *axillary*<sup>1</sup> border. It is divided into nearly equal anterior and posterior parts by a high, thin plate, which stands out at right angles to the surface and runs almost in



LEFT SCAPULA, OUTER ASPECT.

the middle line from the vertebral border to the neck. It is known as the *spine* of the scapula, and it separates the *supraspinous fossa* in front and above from the *infraspinous fossa* below and behind.

The *supraspinous fossa* is bounded in front by the arcuate anterior superior border, above by part of the arcuate vertebral border, and behind by the straight line of attachment of the spine. It is flat from

<sup>1</sup> From *axilla*, the armpit.

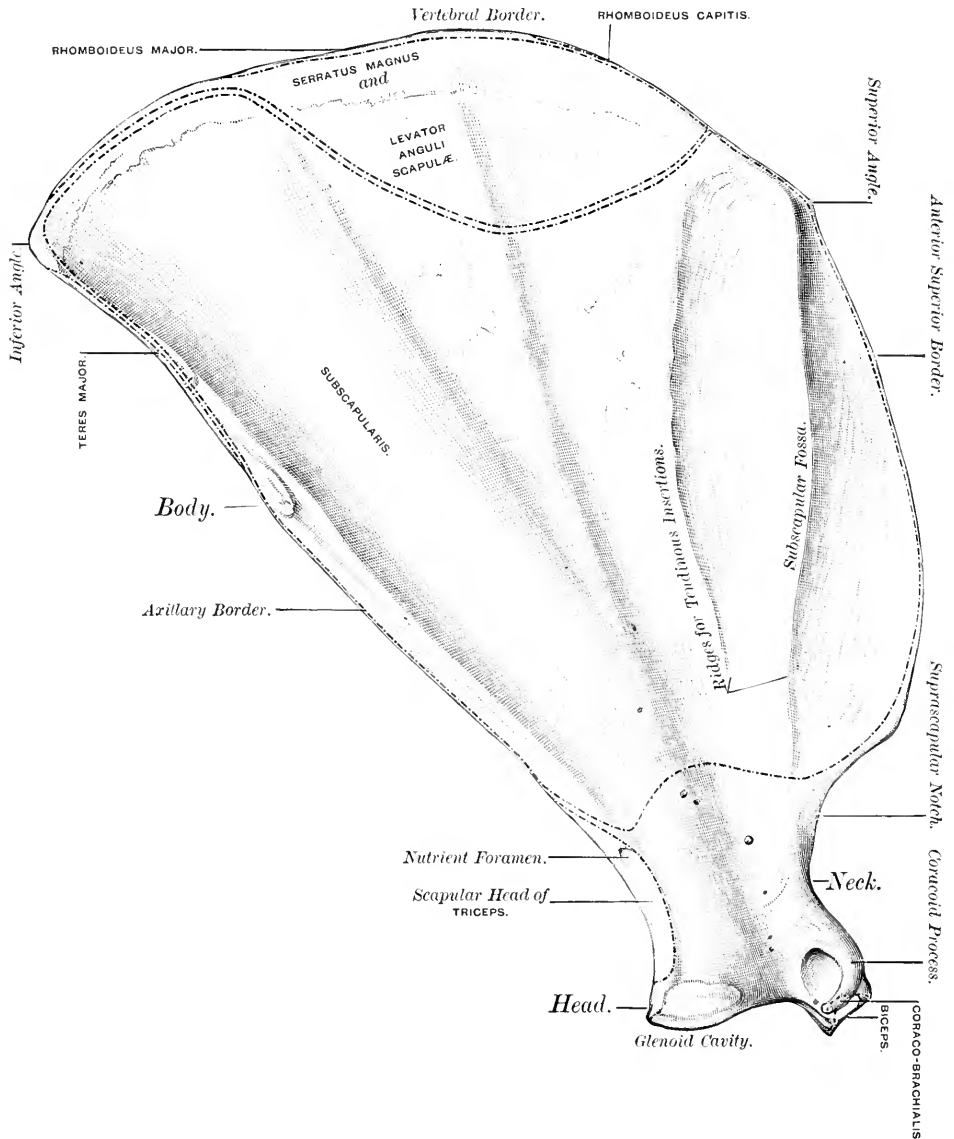
above downward, but concave transversely on each side of the middle line, which is elevated, often into a decided ridge. The scapula is so thin, however, that in the process of drying it may be considerably twisted out of shape; the surfaces will then assume abnormal convexities and concavities. There is usually a vascular foramen at the lower end. The supraspinatus muscle is attached in the supraspinous fossa from the base almost down to the neck.

The **infraspinous fossa** is larger than the supraspinous fossa. It is triangular, wide above and very narrow below. It is nearly flat from above downward, and at the same time concave from before backward, but this is due more to the turning outward of the edges than to the excavation of the surface itself. The fossa is overhung by the posterior surface of the spine. With the exception of a small area below, near the spine, its entire surface gives origin to the infraspinatus muscle. The small area below is often pierced by one or more nutrient foramina.

The **inner surface** of the body of the scapula (Fig. 419) is occupied by the **subscapular fossa**. Its outline is the general outline of the bone, except that a bevelled strip on the posterior edge belongs to the axillary border. It is almost flat, slightly concave in the anterior half, and marked by four or five ridges which begin at the upper end and are directed downward and toward the middle line. The first and more anterior of these ridges, also the best developed and the most constant, begins at the superior angle; the second begins at the vertebral border not far above the superior angle and runs nearly parallel with the first, but is bowed toward the axillary border. The area between these lines is usually concave. The third ridge occupies the middle line of the surface, and is often little more than a slight longitudinal convexity, but sometimes it is a distinct elevated line, more marked above the middle of the surface. On strongly developed bones the upper part of this ridge divides at the level of the anterior angle; one branch runs upward and forward to join the vertebral border near the beginning of the second ridge; the other branch runs backward and upward to the posterior third of the vertebral border. The triangular flattened area included between these branches is part of the area of origin of the serratus magnus and levator anguli scapulae muscles. A fourth ridge begins at or near the vertebral border not far from the inferior angle and runs downward, close to the axillary border, which it sometimes joins below.

The subscapularis muscle arises from the subscapular fossa and from tendinous bands attached to the ridges. The concavity of the subscapular fossa is more marked at the lower anterior part, which is free from muscular attachments and is pierced by one or more vascular foramina.

FIG. 419.



LEFT SCAPULA, INNER ASPECT.

The **Spine** of the scapula is not a pointed spine, but a high ridge produced by a thin bony plate attached by one edge along the middle line of the external aspect. It does not stand out at right angles to the body of the bone, but slopes downward and backward, so that its



slightly convex anterior surface faces upward, forward, and outward and its concave posterior surface faces downward, backward, and inward. The spine is not throughout of the same height; that is, its free edge is not at every point equally distant from the outer surface of the bone.

The free edge begins at the vertebral border in a small triangular flattened area which is smooth and covered by the trapezius muscle. From this point the free edge slopes outward, as well as forward and downward, as far as the middle of the bone, whence it is continued downward and forward and only slightly outward until the spine has attained its maximum height above the surface. The edge is thin and rounded; it is slightly swollen near the middle. The maximum height is reached at some little distance above the lower end, where the edge gives off, quite abruptly, a thin quadrate process which is directed backward, downward, and outward. This process is the **met-acromion**.<sup>1</sup> The lower end of the spine, beyond the metacromion, is continued downward as a pointed process, the acromion.

The **acromion**<sup>2</sup> (Figs. 418, 421) is a thin triangular process, the apex of which points downward and forward. The **outer edge** is continuous with the outer edge of the spine. The **inner edge** runs inward and upward as the lower edge of the spine, and joins the outer surface where the neck joins the body. The acromion thus lies on the outer side of the head and neck of the scapula, and in some cases projects below the head. It is convex from within outward on its **anterior surface**, and slightly concave in the same direction on the **posterior surface**. Its **tip** is connected by fascia with the rudimentary clavicle. The spine, the metacromion, and the acromion afford attachment to a number of important muscles. The posterior part of the supraspinatus muscle arises from the convex anterior surface of the spine and of the acromion. The anterior part of the infraspinatus muscle arises from the greater part of the concave posterior surface of the spine and from the inner surface of the metacromion. The posterior border of the metacromion and the adjoining part of its outer surface receive the insertion of the so-called levator claviculæ muscle. The line of insertion of the trapezius begins below, at the centre of the outer surface of the metacromion, and is continued

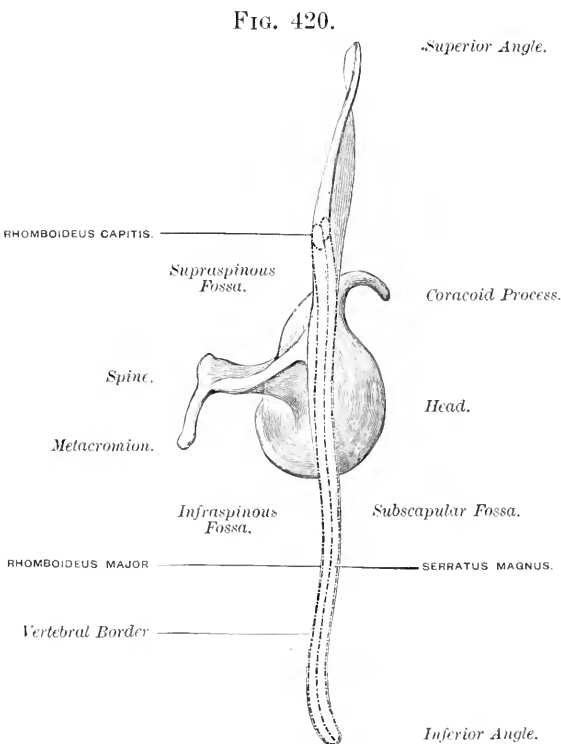
<sup>1</sup> From (Gr.) *meta*, beyond, and *acromion*, the acromion.

<sup>2</sup> From (Gr.) *akron*, a summit, and *omos*, the shoulder.

upward along the anterior part of the edge of the spine to its upper fourth. The lower two-thirds of this line contain the anterior or cervical division of the muscle; the upper third contains the posterior or thoracic division of the muscle. The posterior part of the edge of the spine gives origin to the spinous head of the deltoid, which begins above at the lowest point of insertion of the posterior part of the trapezius and is continued below on the upper edge of the met-acromion. The acromial head of the deltoid arises from the tip, the posterior edge, and the adjoining region of the inner surface of the acromion, and from the anterior part of the lower edge of the met-acromion.

The **vertebral border** (Figs. 418, 419, 420) is arcuate and prolonged downward in front, meeting the anterior superior border in an indistinct **anterior angle**. It forms an obtuse **inferior angle** with the

axillary border. The vertebral border is of about the same width for most of its extent, but where it turns downward in front it is narrower. It is usually margined by a strip of cartilage which gives attachment in front of the middle to the rhomboideus capitis muscle, and behind this area, as far back as the inferior angle, on the outer side and on the adjoining outer surface of the bone, to the rhomboideus major, and on the inner side to the serratus magnus.



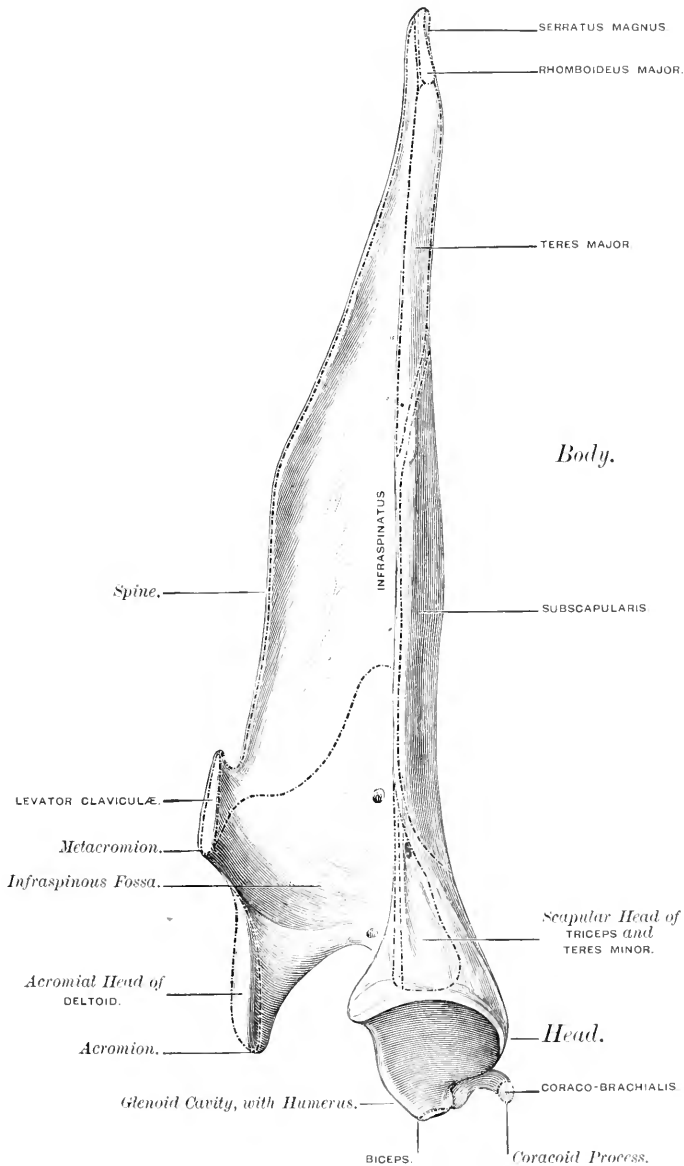
LEFT SCAPULA, VERTEBRAL BORDER.

The **anterior superior border** (Figs. 418, 419) is the shortest of the three borders. It is nearly straight, slightly arcuate, and directed downward and forward. At its lower end it is deeply emarginate to form the **suprascapular notch**. It then becomes

continuous with the anterior borders of the neck and head. It is thin, and serves for the attachment of fibres of the large muscles which arise on the outer and inner surfaces.

The **axillary border** (Figs. 418, 419, 421) is the longest of the three borders. It is straight, or, at most, slightly emarginate above and

FIG. 421.



LEFT SCAPULA, AXILLARY BORDER.

below. It is directed downward and forward; more obliquely forward, however, than the anterior superior border. It is comparatively wide,

and above the middle is divided into two unequal parts by an **oblique ridge** which runs from the inner surface downward to the outer surface. Its upper portion, which comprises about two-fifths of the entire length of the border, is bevelled at the expense of the outer surface to form a narrow, flattened triangle facing outward and backward and giving origin to the *teres major* muscle. The larger lower portion of the border is bevelled at the expense of the inner surface, presenting a long, narrow strip, concave transversely, and facing inward and backward. It is pointed above and more deeply excavated below, where it is continuous with the vertebral surface of the neck and head. For most of its extent it gives origin to the posterior part of the *subscapularis* muscle, but on its lower end to the upper, or dorsal, part of the tendon common to the *teres minor* and the scapular head of the *triceps*. At the lower end of this border are several vascular foramina.

Of the three angles of the scapula, the **inferior angle** is at the junction of the vertebral and axillary borders, which if produced would form a right angle; the **superior angle**, the meeting point of the vertebral and anterior superior border, is an obtuse angle, and is not prominent. The **anterior angle** is truncate, and is known as the head.

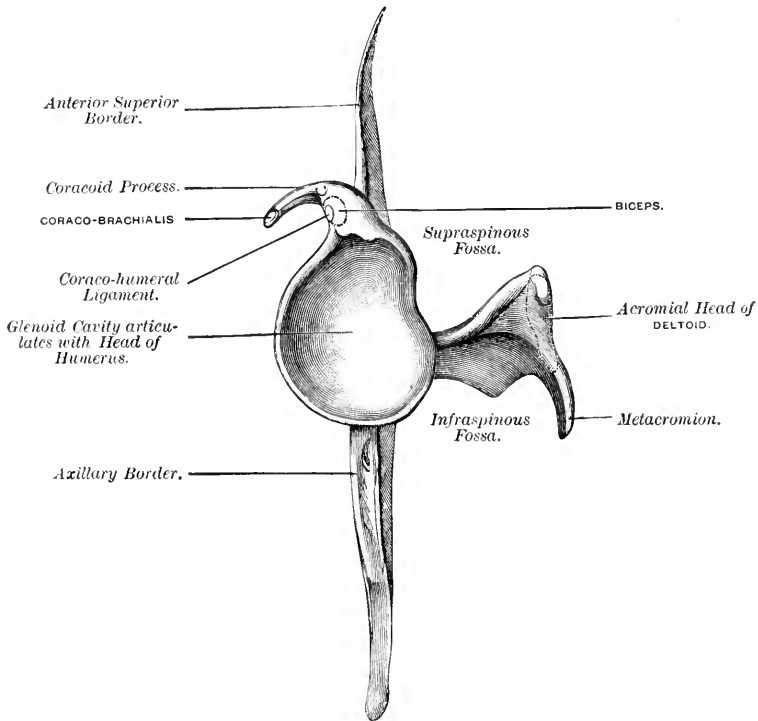
The **Neck** (Figs. 418, 419) of the scapula is the constriction which divides the body from the head. It is little more than a line encircling the bone. It is marked in front as the deepest point of emargination of the suprascapular notch, and on the outer surface by a more or less well defined groove which passes below the root of the lower edge of the spine. The neck gives attachment to the capsular ligament of the shoulder joint. Below the neck the surfaces of the scapula rise in all directions to form the head.

The **Head** of the scapula (Figs. 418, 419, 421, 422) occupies the anterior angle of the bone. It is the thickest part of the scapula, but is not much longer from before backward than the neck. It gives off from its anterior inner part the curved finger-like **coracoid process**. The head presents for examination four surfaces and one border.

The **lower surface** (Fig. 422) is pear-shaped; the transverse diameter is a third less than the antero-posterior diameter; the smaller end points forward, joining the lower end of the anterior border. The lower surface is entirely occupied by a moderately deep glenoid cavity for articulation with the rounded head of the humerus.

The **glenoid cavity** is gently concave in all directions, and for the most part faces downward and forward; the anterior smaller end, however, faces downward and backward. This change in the direction of the surface is due to the presence at its anterior end of a small conical process known as the **supraglenoid tubercle**, to which the

FIG. 422.



LEFT SCAPULA LOWER END.

tendon of origin of the biceps muscle is attached. The surface of the glenoid cavity is covered with a layer of articular cartilage, and its margins, which in the dried bone are low and rounded, are heightened and rendered thin by a cartilaginous ring, thus deepening the articular cavity.

The **posterior surface** (Fig. 421) of the head is the downward continuation of the axillary border of the body, from which, however, it slopes downward and inward. At the margin of the glenoid cavity and a little above, it is strongly convex transversely; above this again it has the same direction as the vertebral border and faces backward and inward; it is excavated and roughened. It gives origin to the teres minor and the scapular head of the triceps muscle.

The **anterior border**, the continuation of the anterior superior

border of the body, is directed downward, forward, and inward, continuous with the upper border of the coracoid process.

The **outer surface** of the head (Fig. 418) consists of three regions:

(1) In front, occupying the anterior half, is a smooth, convex triangle, which, facing outward and forward, turns inward and forward to become the anterior surface of the coracoid process. It is pointed below on the supraglenoid tubercle. The edge behind this part is the margin of the glenoid cavity; in front of the tubercle it runs upward and forward; it is sometimes flattened and sometimes notched, and gives origin to the biceps and the coraco-humeral ligament. It ends by turning inward to become the lower border of the coracoid process.

(2) Behind this triangular convexity on this surface of the head is a narrow, flattened strip, lying below the spine.

(3) Behind this strip is a wider portion which turns inward and upward and is continuous with the infrapinnous fossa.

The **inner surface** of the head (Fig. 419) is alternately convex and concave from before backward. From the lower, sinuous glenoid border it slopes upward and outward. In front it curves inward and backward on the posterior surface of the coracoid, and below the root of this process it runs downward and forward on the supraglenoid tubercle. At this point it often presents a decided circular fossa.

The **coracoid process**<sup>1</sup> (Figs. 419, 422) springs from the inner lower edge of the anterior border. It is wider at the base than at the tip, and slightly less thick than wide. It is directed downward and inward and curves backward. Its **outer surface** is therefore convex in both directions and faces inward, forward, and upward. The **posterior surface** is concave from above downward and from without inward; it therefore faces backward, outward, and downward. The **tip** is evenly rounded, and gives attachment to the tendon of origin of the coraco-brachialis muscle.

**Nomenclature.**—The word *Scapula* is used in the plural by classical Latin authors to denote the back as contrasted with the breast. In the Middle Ages *spathula*, the diminutive from the Greek *spade*, and applied to a number of flat objects, was employed for the shoulder-blade, but by the time of Vesalius it had been replaced by *scapula*. Aristotle and Galen called the bone *omoplate*, from *omos*, the shoulder,

<sup>1</sup> From (Gr.) *corax*, a raven, and *eides*, like, because of a fancied resemblance to a raven's beak.

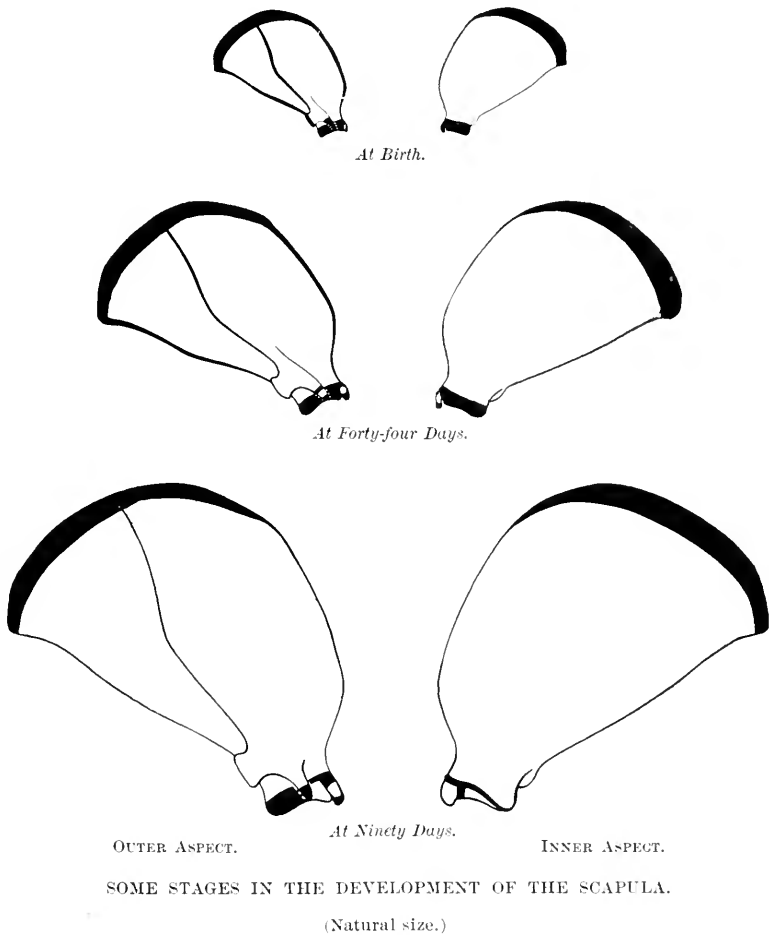
and *plate*, a plate, which is retained in the Latin synonym *omoplata* and in the French term *l'omoplate*. The German synonym is *das Schulterblatt*.

**Determination.**—If the scapula be held with the head downward and the spine toward the student, the coracoid process will be on the side to which the bone belongs.

**Articulation.**—The scapula articulates with the humerus.

**Muscular Attachments.**—The following muscles are attached to the scapula: to the vertebral border, the *rhomboideus capitis*, the *rhomboideus major*, and the *serratus magnus*. To the axillary border, the *teres major*, the *teres minor*, and the *triceps*. To the

FIG. 423.



external surface, the *supraspinatus* and the *infraspinatus*. To the spine, the *trapezius*, the *deltoid*, the *levator claviculæ*, the *supraspinatus*, and the *infraspinatus*. To the inner surface, the *serratus*

*magnus*, the *levator anguli scapulæ*, and the *subscapularis*. To the head, the *biceps* and the *coraco-brachialis*.

**Blood Supply.**—The scapula is supplied with blood mainly by the *suprascapular* and *subscapular* arteries. The general distribution of the *suprascapular* artery is to the *supraspinous fossa* and the distal anterior end of the *subscapular fossa*, while the *subscapular* artery enters the bone in the *infraspinous fossa*, the axillary border, and the proximal end of the *subscapular fossa*.

**Ossification.**—The scapula appears to develop from at least four principal centres (Fig. 423). The first to appear is the centre for the body and the spine; then small centres appear in the *acromion* and *metacromion*. At about forty days the *coracoid* process begins to ossify; at seventy days a centre begins in the upper part of the *glenoid cavity*. The margin of the vertebral border and the tips of the *coracoid* process and *acromion* remain for a long time cartilaginous.

#### VARIATIONS IN THE SCAPULA.

##### VARIATIONS IN SIZE.

The measurements of the scapula are taken as follows:

The breadth is the diameter on a line from the vertebral border at the origin of the spine to the middle of the inner edge of the head.

It would be more natural to call this diameter the length, because on the scapula of the cat it is the greater, but, inasmuch as it is termed the breadth in human anatomy, for purposes of comparison it will be more convenient so to designate it in the table.

The length is the diameter from the superior angle to the inferior angle.

The width of the *supraspinous fossa* is the distance taken on the length of the scapula from the superior angle to the edge of the spine.

The width of the *infraspinous fossa* is the distance taken as above from the inferior angle to the edge of the spine.

These two diameters are not absolutely correct, owing to the fact that the edge of the spine overhangs the *infraspinous fossa*.

The long diameter of the *glenoid cavity* is the antero-posterior diameter from the tip of the *supraglenoid tubercle* to the posterior margin.

The short diameter is the greatest transverse diameter.



Side.	Breadth.	Length.	Width of infra- spinous fossa.	Width of supra- spinous fossa.	Glenoid Cavity.	
					Long diameter.	Short diameter.
Right . . . . .	53	43.5	24	17	10	7.5
Left . . . . .	55	55.5	25.5	16.5	10.5	8
Left . . . . .	56	41	24	18	10	8
Right . . . . .	56.5	43	24.5	19	10	8
Left . . . . .	56.5	49	28	24	11	9
Right . . . . .	57	46	28	20	11	8
Left . . . . .	57.5	46	28	20	11	8
Left . . . . .	57.5	46.5	27	21	10	8
Left . . . . .	57.5	47.5	27	21	11	9
Left . . . . .	57.5	47.5	28	21	11	11
Left . . . . .	57.5	48.5	28.5	18	11	8.5
Right . . . . .	58	46	28	22	10	8
Left . . . . .	58.5	48	27	22	10	8
Right . . . . .	59.5	45.5	26	21	11	9
Right . . . . .	60	46.5	29	20	11	9
Right . . . . .	60	48.5	28	18	10.5	7.5
Left . . . . .	60	50	29	20	10	9
Left . . . . .	60.5	51	30.5	22.5	12	9
Right . . . . .	61	45	26	15	11	7
Left . . . . .	61	45	27	19	10	8
Right . . . . .	61	46.5	27	20	11	9
Right . . . . .	61	50	29	23	12	9
Right . . . . .	61	51	29	24	11	10
Left . . . . .	61.5	45	28	17	10.5	9
Left . . . . .	61.5	49.5	28	19.5	11	8
Right . . . . .	61.5	50	30	20	12	10
Left . . . . .	61.5	51	28	24	12	9
Left . . . . .	62	47	26	22	11	9
Left . . . . .	62.5	52.5	28.5	22	12	9
Right . . . . .	63	50	30	23	13	9
Left . . . . .	63	54	30	24	11	9
Right . . . . .	63	56	34	22	12.5	10
Right . . . . .	63	56.5	28.5	20.5	11.5	9
Right . . . . .	64	52	31	23	12	9
Left . . . . .	64	53.5	33	23	12	10
Right . . . . .	65	52	30	24	12	10
Right . . . . .	66.5	53.5	32	22	12	11
Left . . . . .	67	54.5	34	23	12	10
Right . . . . .	68	56	30.5	20	13	9
Right . . . . .	70	58	33.5	26	13.5	11
Right . . . . .	70	58.5	33	24		10
Right . . . . .	70	59	35	26	13	10
Right . . . . .	73	61	35	28	13	10.5

## VARIATIONS IN FORM AND DEVELOPMENT.

The scapula exhibits variations in form, due principally to modifications in the relations between the length and the breadth. In some cases the **supraspinous fossa** more nearly equals the **infraspinous fossa**.

The **superior angle** is occasionally indistinct and rounded, but in a small proportion of specimens it is as distinct as the **inferior angle**.

The **spine** varies slightly in the angle it makes with the surface of

the scapula, and also in the position of its highest point. Its edge may be almost straight or strongly sinuate, and either sharp for the greater part of its extent or in part or wholly flattened and retroverted.

The **metacromion** is quadrate, triangular, or rounded, and rarely not defined above from the edge of the spine. The degree of its introversion also varies.

The **acromion** presents at least two variations in direction. In one form its long axis is a continuation of the long axis of the spine, and its tip projects below the glenoid cavity when the bone is seen directly from the side; in the other form the axis is bent forward from the axis of the spine, and the tip is opposite the neck of the bone. The tip is pointed, or blunt, swollen, and slightly bifid; traces of the epiphyseal suture are sometimes visible.

The triangular flattened region at the top of the axillary border for the *teres major* is rarely wanting.

The **suprascapular notch** varies in depth and in the degree of prominence of the angle which its upper limit forms with the anterior superior border.

The **subscapular fossa** varies, of course, in form, and also in the degree of development of its tendinous ridges. Rarely the ridges are practically absent. The third ridge is frequently wanting. The bevelled area along the axillary border may be broad and obscurely defined from the rest of the surface. The depression at its lower end may be deepened into an excavation.

The **coracoid process** is measurably constant, varying slightly in its direction and in the acuteness or bluntness of its tip.

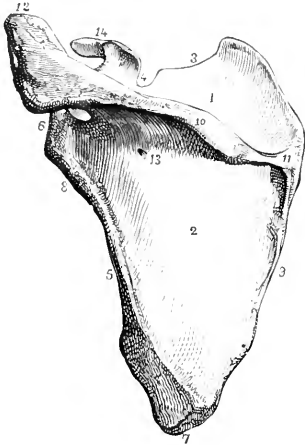
The **supraglenoid tubercle** appears to be always present, although at times it is small and rounded. The general outline of the **glenoid cavity** is constant, but it may vary in size and in relative breadth from without inward. The area of origin of the scapular head of the *triceps* on the axillary border sometimes encroaches on the lower margin of the cavity and makes it straight; occasionally the tendon of the *supraspinatus* grooves the upper outer margin.

#### HUMAN SCAPULA.

The scapula of man (Figs. 424, 425) presents all the parts shown in the scapula of the cat except the **metacromion**. It has in addition an **articular facet** on the inner border of the **acromion**, for union with the

clavicle. The secondary points of difference between the two forms are those which are associated with man's upright posture and the use of the anterior extremity for other purposes than the support of the body. (See Figs. 435, 436.) The position of the human scapula is

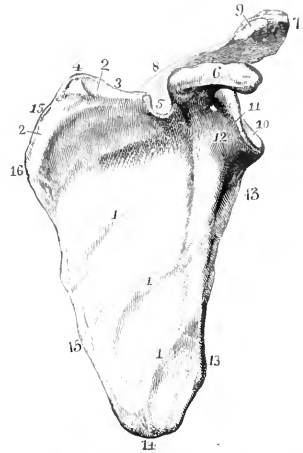
FIG. 424.



LEFT SCAPULA, POSTERIOR VIEW.

1, supraspinous fossa; 2, infraspinous fossa; 3, superior border; 4, coracoid notch; 5, inferior border; 6, glenoid cavity; 7, inferior angle; 8, neck of the scapula; 9, posterior border or base; 10, spine; 11, its triangular commencement, upon which the tendon of the trapezius muscle moves; 12, acromion; 13, one of the nutrient foramina; 14, coracoid process.

FIG. 425.



LEFT SCAPULA, ANTERIOR VIEW.

1, ridges crossing the subscapular fossa; 2, attachment of the serratus muscle; 3, superior border; 4, superior angle; 5, coracoid notch; 6, coracoid process; 7, acromion; 8, spine of the scapula; 9, articular surface for the clavicle; 10, glenoid cavity; 11, elevated margin of the same; 12, neck; 13, inferior border; 14, inferior angle; 15, base; 16, position at which the spine commences.

more dorsal, the inferior angle is at the lowest point, and the glenoid cavity faces forward and outward. In form it is triangular, but the long diameter is from the superior to the inferior angle, and the short diameter from the head to the vertebral border.

The **external surface** is posterior; the supraspinous fossa is small, and the infraspinous fossa is large.

The base of the **spine** is short; its edge is flattened, and its outward continuation, the acromion process, is curved, broad, and quadrate, projecting far beyond the head.

The **superior border** is relatively shorter, and as a rule the suprascapular notch is smaller and more distinctly marked.

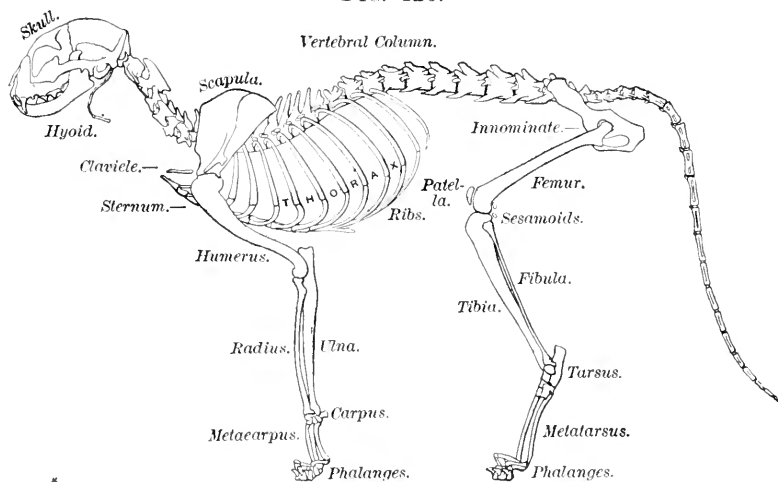
The bevelling on the **axillary border** at the expense of the dorsal surface is more extensive, and is for the origin of the teres minor as well as of the teres major muscle.

The **subscapular fossa** is deepest along a line corresponding with the attachment of the spine to the dorsal surface.

The coracoid process is relatively longer and projects beyond the head. The outline of the glenoid cavity is similar, but normally the supraglenoid tubercle is smaller.

### THE HUMERUS.

FIG. 426.



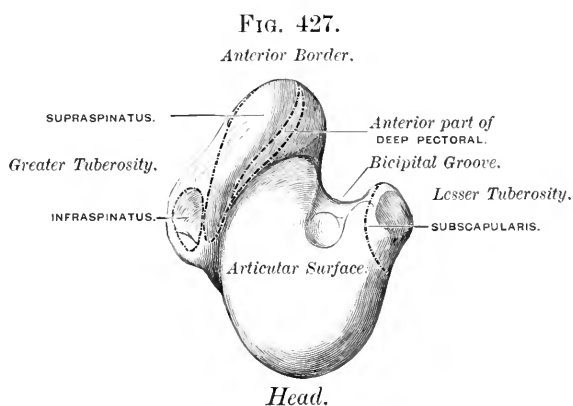
THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

**General Description.**—The Humerus is the single, long cylindrical bone of the arm. Its articulation above with the shoulder girdle at the glenoid cavity of the scapula forms the shoulder-joint, and its articulation below with the upper ends of the radius and the ulna forms the elbow-joint. It is covered with muscles, through which its size and form can be easily distinguished. The upper end constitutes the prominence of the shoulder, and the lower end the point of the elbow. The humerus has a considerable range of motion at the shoulder-joint, and at rest usually it occupies a more or less oblique position, with the upper end directed forward and the lower end directed backward. As this position is not constant, for convenience of description the bone may be held vertically, with the upper and larger end above, and the anterior surface, which is convex from above downward, in front. The length of the humerus is from twelve to fourteen times greater than the width at the middle part of the shaft. It is in the main straight, except where bent backward at the upper end. The greatest diameter of the upper part, which is the antero-posterior diameter, is contained about four and a half times in the greatest length of the bone, and the greatest diameter of the lower end, which is the transverse, is contained about five times in the length.

The humerus consists of a central shaft and an upper and a lower extremity.

The **Upper, or Proximal, Extremity** is the larger end of the bone. It is not sharply separated from the shaft, but passes gradually into it below. Its greatest antero-posterior diameter is at least a third greater than its greatest transverse diameter. It is deeper from before backward than any other part of the bone, but its transverse width is exceeded by the transverse width of the lower end. It comprises a median posterior head, an outer greater tuberosity, and an inner lesser tuberosity.

The head of the humerus is the enlarged rounded swelling on the posterior part of the upper extremity. When seen from above (Fig. 427), its outline is rudely lozenge-shaped, pointed in front and behind, and widest at about the middle. The antero-posterior diameter is somewhat greater than the transverse diameter. The convex superior surface has the general outline of the head. It is limited in front on the outside by



LEFT HUMERUS, PROXIMAL END.

a faint groove which curves backward and outward along the base of the greater tuberosity; it is limited on the inner side by the emarginate upper edge of the bicipital groove, and by a roughened line passing backward and inward along the base of the lesser tuberosity. The surface is bounded behind, on the outside and on the inside, by a roughened, jagged line which is part of the line of union of the upper epiphysis with the shaft. The surface is convex in all directions, but more strongly behind, where the obtusely rounded point turns downward and overhangs the posterior border of the bone. It is everywhere smooth; in some specimens, however, the emargination for the bicipital groove is continued backward and produces a shallow depression near the anterior margin. The articular surface of the head of the humerus is covered with cartilage and is received into the glenoid cavity of the scapula.

The head of the humerus presents behind (Fig. 431), below the jagged line which limits the articular surface, **external and internal surfaces** lying between the upper ends of the internal border and the deltoid ridge and separated by a ridge which is the beginning of the posterior border of the bone. These surfaces are excavated, roughened, and pierced by venous foramina. They are continuous with the posterior and external surfaces of the shaft, and give origin to the upper part of the posterior humeral head of the triceps muscle.

The **greater tuberosity** (Figs. 427, 428) is a broad, flattened process applied to the front of the outer side of the head in such manner that the narrow upper edge projects above the articular surface, and the external surface faces outward and forward.

The **superior border** is a rounded convex crest which begins behind as a line at the upper end of the deltoid ridge. It widens gradually as it arches upward, and then, becoming more flattened and facing inward, curves down to the front; here, at a roughened swelling, it changes slightly its direction, and, becoming a rounded **anterior border**, passes straight down into the anterior border of the shaft.

The **internal surface** of the greater tuberosity (Fig. 427) is pointed above and behind, and wide below. At first it forms the anterior external wall of the articular surface of the head and faces inward and backward, but lower down it becomes wider and rougher, faces almost directly inward as the outer wall of the bicipital groove, and is continuous below with the inner surface of the shaft.

The superior and anterior borders and the edges of the adjoining surfaces of the greater tuberosity give insertion to the supraspinatus muscle, and the internal surface, near the articular surface and the bicipital groove, to the anterior part of the deep pectoral and the upper portion of its posterior part.

The **external surface** of the greater tuberosity is bounded above by the arcuate superior border, in front by the arcuate anterior border, and behind by the sharp emarginate beginning of the deltoid ridge. It passes below, without change of direction, into the external surface of the shaft; in the bone of a young specimen its lower limit is often seen as an arched line more or less distinct crossing the surface and indicating the point of union of the epiphysis with the shaft. The surface is divided into anterior and posterior parts by a roughened line which begins behind the middle of the upper margin and runs

downward and backward to the posterior inferior angle. The anterior triangular portion is flat, slightly roughened, and pierced by foramina for veins. It faces outward and forward, and is free from muscular attachment. The posterior smaller portion is ovoid in outline and faces outward and backward. Its upper part is rough and depressed; it is the area of insertion of the tendon of the infraspinatus muscle. The lower part is slightly elevated, particularly at the lower angle, for the attachment of the teres minor muscle and the upper end of the outer humeral head of the triceps muscle.

The **lesser tuberosity** of the humerus (Figs. 429, 430) is closely united with the head, so closely, indeed, that it appears little more than its enlarged anterior internal portion. It is very much smaller than the greater tuberosity, from which it is separated in front by the bicipital groove and behind by the entire width of the head. It is oblong, and the long diameter, which is twice as great as the transverse diameter, is directed from above downward and backward. It is divided by an internal border into anterior and posterior surfaces.

The **internal border** begins above at the prominent superior angle behind the bicipital groove; it then arches downward and backward, and at the inferior angle bends abruptly forward and outward to continue downward as the internal border of the shaft.

The **quadrilateral anterior surface** of the lesser tuberosity is concave from side to side, convex from above downward at the upper part, and almost flat below. It faces forward, outward, and slightly downward. It forms part of the floor and the inner wall of the bicipital groove; it is limited below by the internal border.

The **posterior surface** of the tuberosity is long and narrow; it is flattened from side to side, and is convex from above downward; the upper part faces upward, backward, and outward, and the lower part faces outward and backward. It is limited in front by the inner border of the tuberosity, and behind by a faint groove which separates it from the articular surface of the head. It has a short, obscure superior margin, directed inward and backward, and is defined clearly below by a short arcuate line, below which, and behind the beginning of the internal border of the shaft, is the outer part of the posterior surface of the head, continuous below with the posterior surface of the shaft. The subscapularis muscle is attached to the entire posterior surface of the lesser tuberosity.

The **bicipital groove** (Fig. 429) is a wide and shallow excavation, situated on the inner side of the front aspect of the upper extremity of the humerus below the head and between the two tuberosities. It is deepest and widest above, but below passes on to the internal surface of the shaft. It lies at the line of meeting of the anterior part of the internal surface of the greater tuberosity with the anterior surface of the lesser tuberosity, the former forming its outer wall, the latter its floor. The bicipital groove lodges and holds in place the tendon of the biceps muscle, which is attached just above the shoulder-joint to the coracoid process of the scapula. On its outer wall is inserted the posterior part of the deep pectoral muscle.

The **Shaft** of the humerus comprises the greater part of the bone, and is the longer, slender portion between the two extremities, from which it is not sharply defined. When seen from in front, it appears straight, slightly narrowed below the middle, and widening out at the ends. When viewed from the side, the upper part is seen to curve backward and to have an antero-posterior diameter nearly twice as great as the antero-posterior diameter of the lower part. The shaft is divided by anterior, internal, and external borders into internal, posterior, and external surfaces.

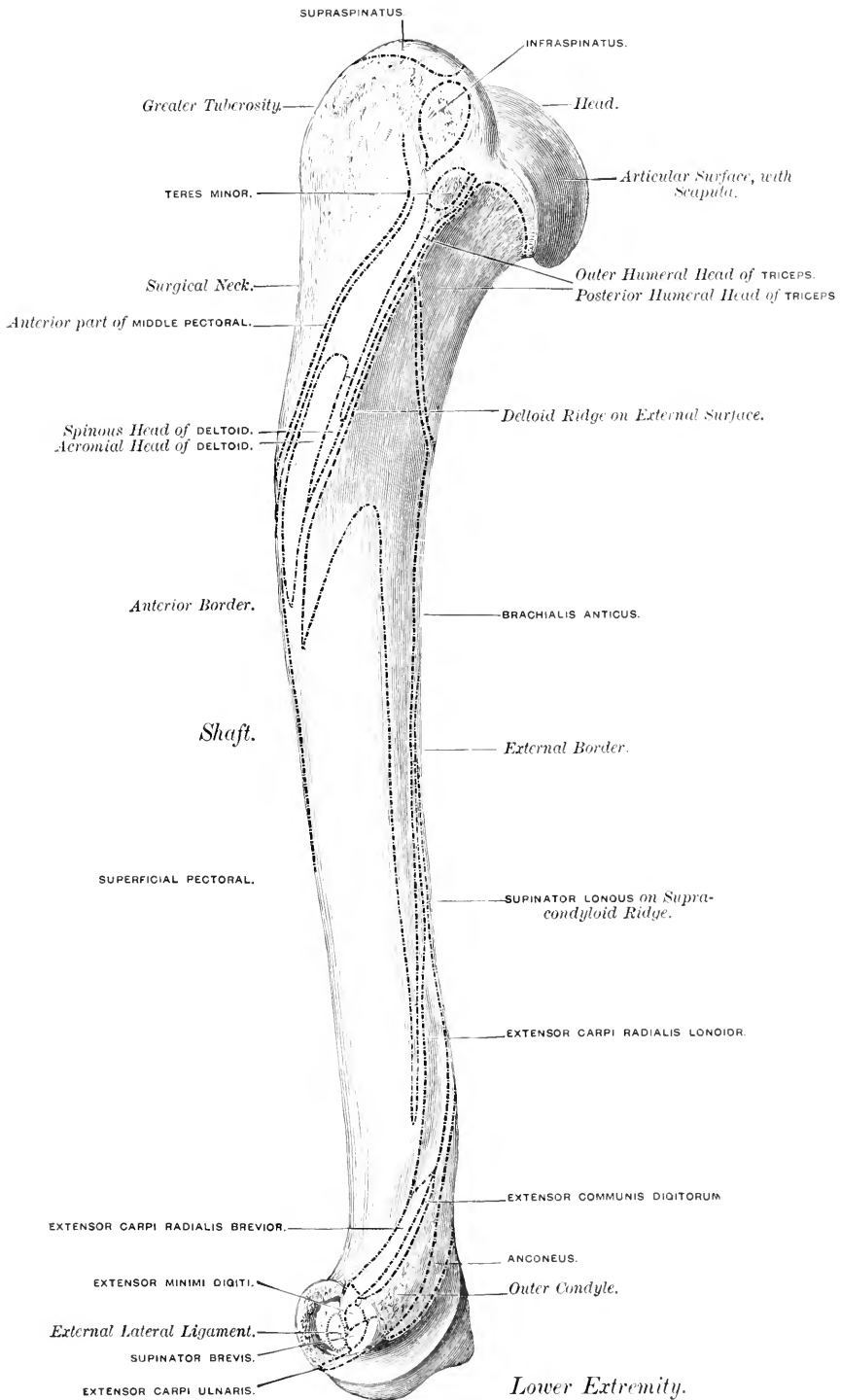
The **anterior border** (Fig. 430) begins above as the continuation of the anterior border of the greater tuberosity, and runs downward, on the inner side of the front of the bone, to a variable point, where it fades away, permitting the external and internal surfaces to become continuous in the lower third. In its upper third it is broad and rounded, and is directed inward as well as downward; it then turns outward, and becomes narrower and sharper, and finally obscure. It practically ends when it is joined by the lower end of the strong oblique line on the external surface, called the **deltoid**<sup>1</sup> ridge, but traces of it are often seen below, in one or more lines for muscular insertion directed toward the inner angle of the lower extremity. On the inner side of the upper half of the anterior border is inserted the aponeurosis of the posterior part of the deep pectoral muscle, below which the lines of insertion of the middle pectoral and the superficial pectoral, which begin above on the external surface, are continued on the border downward to its end.

The **external border** (Fig. 428) is posterior in its upper two-thirds

<sup>1</sup> From *delta*, the Greek letter Δ, and *eides*, like.



FIG. 428.  
*Upper Extremity.*



*Lower Extremity.*

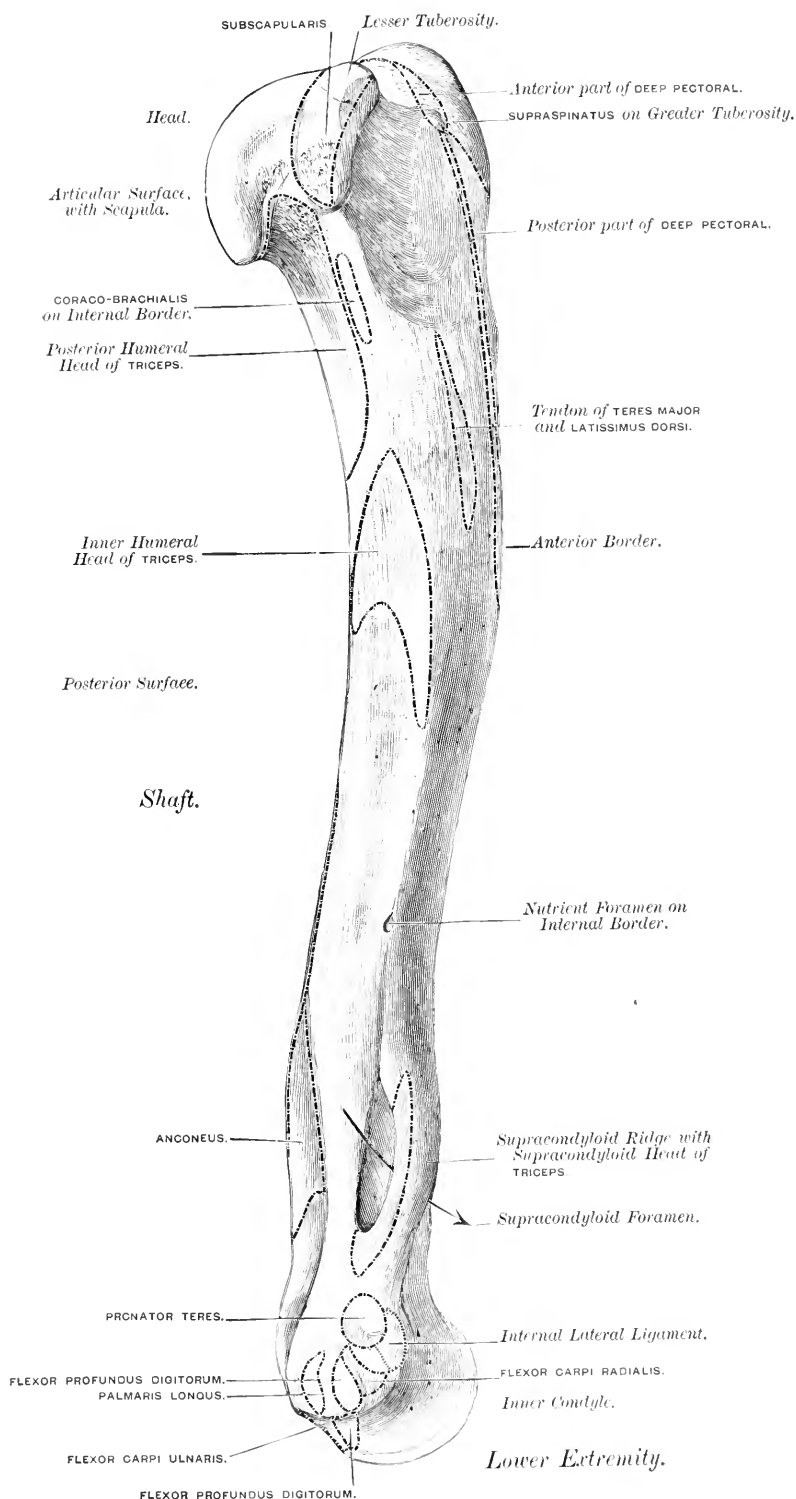
LEFT HUMERUS, OUTER ASPECT.

and posterior and external in the lower third. It arises above in the posterior middle line, below the overhanging posterior hook of the articular part of the head. It is smooth, rounded, and not prominent; it passes gradually outward to reach the external aspect of the bone below the middle; here it becomes sharper, and, as the **external supracondyloid ridge**, is continued on the lower extremity of the bone, where it forms the anterior margin of its external surface. The upper part of the external border is included in the area of insertion of the posterior humeral head of the triceps muscle on the adjoining posterior and external surfaces. Below this area is attached a strong aponeurosis, which gives common origin above to the brachialis anticus, the supinator longus, and the anconeus, and at the lower part to the extensor carpi radialis longus, extensor radialis brevis, anconeus, and extensor communis digitorum muscles.

The **internal border** (Fig. 429) is not well defined. It begins above at the lower end of the lesser tuberosity as a prominent, rounded ridge; it then arches forward and downward for from five to fifteen millimetres parallel with the external border and not far from it, but is soon lost, and is hardly manifest again until it appears below as the ridge limiting the anterior edge of the supracondyloid foramen. On its course, considerably below the middle, is the well-marked **nutrient foramen** piercing the bone obliquely downward and inward; it transmits the principal artery of the shaft. The coraco-brachialis muscle is inserted into the prominent upper part of this border. Lower down the anterior edge of the shield-shaped area of origin of the inner humeral head of the triceps reaches the internal border. For the rest of its course it is free from muscular attachment.

Of the three surfaces into which the shaft is divided, the **external surface** (Fig. 428) is the largest, equalling in extent both the posterior and internal surfaces together. It lies between the anterior and the external border. Owing to the position of the external border, it is wider above than below. Above, it faces forward and backward as well as outward, and below, in front of the supracondyloid ridge, it faces forward as well as outward. Its upper part, nearly a half of the surface, is divided into two parts by the oblique **deltoid ridge**, which begins above at the back of the greater tuberosity, is directed downward and forward, and joins the anterior border of the shaft at or below its middle. The triangular area above and in front of this line

FIG. 429.  
*Upper Extremity.*



LEFT HUMERUS, INNER ASPECT.

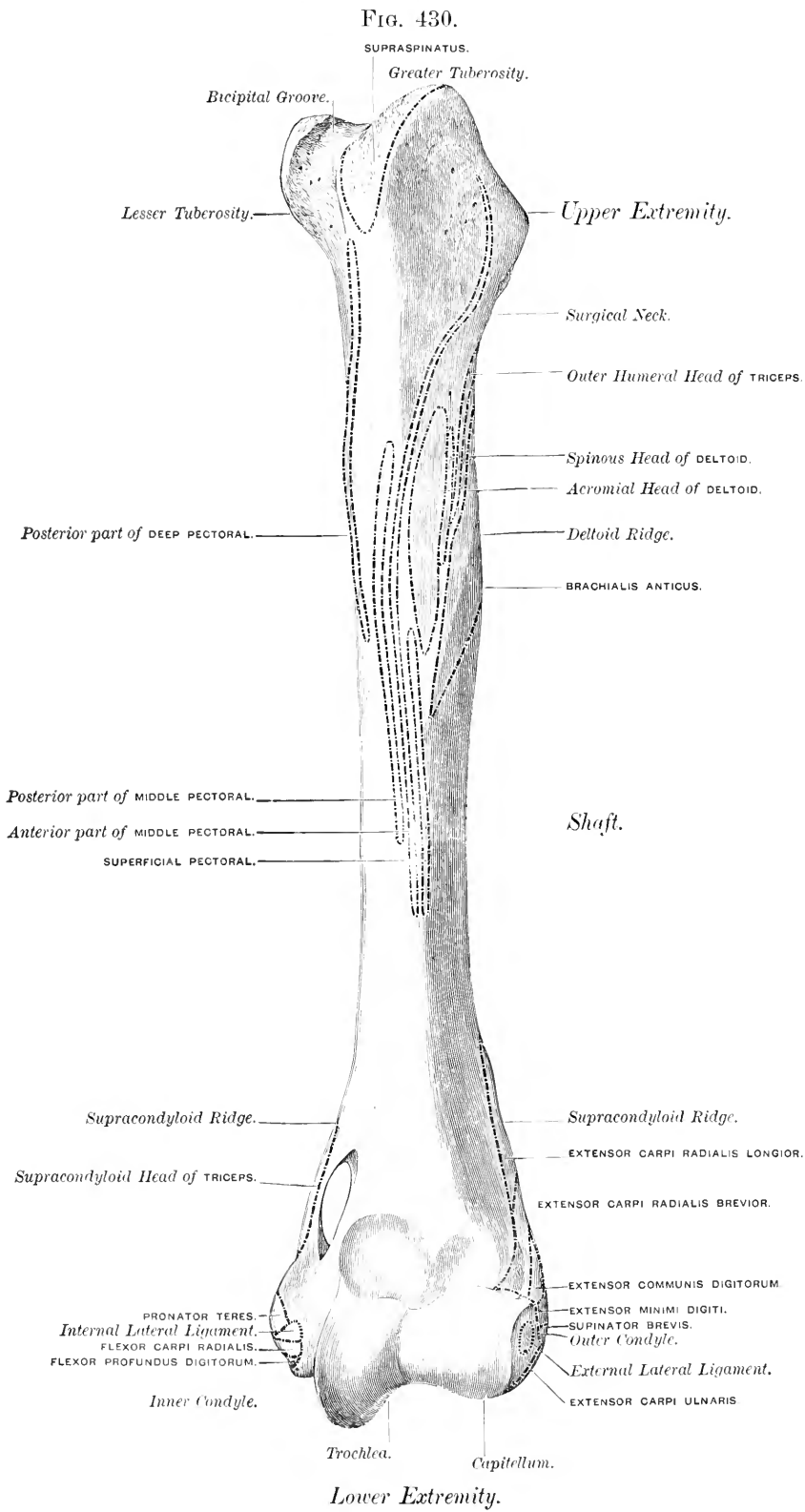
is continuous above with the external surface of the greater tuberosity. It is gently convex from side to side and slightly depressed at the middle. The surface is twisted upon its own axis in such manner that the upper part faces much more outward than forward and the lower part faces more forward than outward. Along its middle is attached the aponeurosis of the anterior part of the middle pectoral; lower down, at the apex, is inserted the acromial head of the deltoid muscle, behind and above which, on the deltoid ridge, is the insertion of the spinous head of the deltoid. The upper anterior part of the surface is rough and free from muscular attachment. Above the deltoid ridge, the tendon of origin of the outer humeral head of the triceps is attached. The portion of the external surface remaining is a curved strip everywhere of almost equal width, bounded in front by the deltoid ridge and the anterior border and behind by the external border. It is continuous below with the external surface of the lower extremity; above it faces outward and downward, and below outward and forward. It is smooth and convex from side to side, more strongly at the middle, and slightly concave from above downward, at the upper and lower ends. The outer part of the area of origin of the posterior humeral head of the triceps occupies a small triangle of the surface at the upper end, below which is the area of origin for the brachialis anticus, which is continued downward as a strip along the deltoid ridge and a strip along the external border. The rest of the surface, although covered with muscles, is free from muscular attachment.

The internal surface (Fig. 429) is the smallest of the three; it lies between the anterior and internal borders, and by reason of their direction is wider above than below. Its upper third is directed backward and upward away from the long axis of the lower two-thirds, and passes above into the bicipital groove, the anterior surface of the lesser tuberosity, and the internal surface of the greater tuberosity. Below, it is continuous with the surface of the bony bridge over the supracondyloid foramen. The internal surface is convex from side to side, except above, where it is the continuation downward of the bicipital groove; from above downward it is gently concave. It faces forward and inward, and is smooth, unmarked by roughened areas for muscular attachment, except on a small line in the upper fourth, behind and parallel with the anterior border, to which line the conjoined tendon of the teres major and the latissimus dorsi muscle

is attached. This is not always well marked. To the outer margin of the supracondyloid foramen, which may be regarded as the lower posterior edge of the internal surface, is fastened the supracondyloid head of the triceps muscle.

The **posterior surface** (Fig. 431) lies between the internal and external borders. It is concave from above downward by reason of the direction backward of its upper third. Its edges, which are nearly parallel for almost their entire extent, diverge below. The lower third of the posterior surface is divided by a longitudinal ridge into two parts, whereof the inner is principally occupied by the oblong **supracondyloid foramen** and the groove above leading into it, and faces outward and backward. The outer part, which is at least twice as wide as the inner, faces more nearly directly backward, and is occupied by a triangular depression, shallow at the apex above, but deepening below into the deep cavity on the lower extremity just above the articular surface. This depressed area receives the upper end of the ulna when the forearm is extended, and is known as the posterior supratrochlear or **olecranon fossa**. The posterior surface above the lower end faces inward and backward, and is convex from side to side, except at the extreme upper end, which is flat or slightly concave transversely. It is smooth and without muscular markings. The following muscles, however, are attached to it: The posterior humeral head of the triceps arises in part from the upper fourth; below its area of origin, separated from it by an oblique space, is the area for the origin of the inner humeral head of the triceps. This area has the shape of an inverted shield, with the angle nearest the internal border prolonged downward. The anconeus arises in part from the upper part of the inferior triangular depression already described.

The **Lower Extremity** of the humerus differs from the upper extremity in several important particulars. It is compressed from before backward and expanded from side to side, while the upper extremity is compressed laterally and prolonged backward. It articulates by a hinge-joint, moving in an antero-posterior plane with the upper ends of the two bones of the forearm, while the upper extremity articulates by a ball-and-socket joint with one bone only, the scapula. The lower extremity is twisted on the long axis of the bone in such manner that its anterior surface faces outward as well as forward; the upper extremity is twisted in like manner, but to a less marked



LEFT HUMERUS, ANTERIOR ASPECT.

degree. The lower extremity consists of three parts,—two lateral prominences and a middle prominence. The two lateral prominences, one on each side, are called the **outer** and **inner condyles**. The area between them comprises a lower transverse roller-shaped **articular eminence**, bounded in front and behind by a depressed non-articular space. When the bone is held vertically the inner sharp edge of the articular eminence is the lowest point of the extremity. The inner condyle is the larger, and it appears to project slightly further downward. The widest part of the extremity is between the points of the condyles, considerably above the line of the articular surface. From this point it becomes narrow as it ascends to join the shaft and as it descends to join the articular eminence.

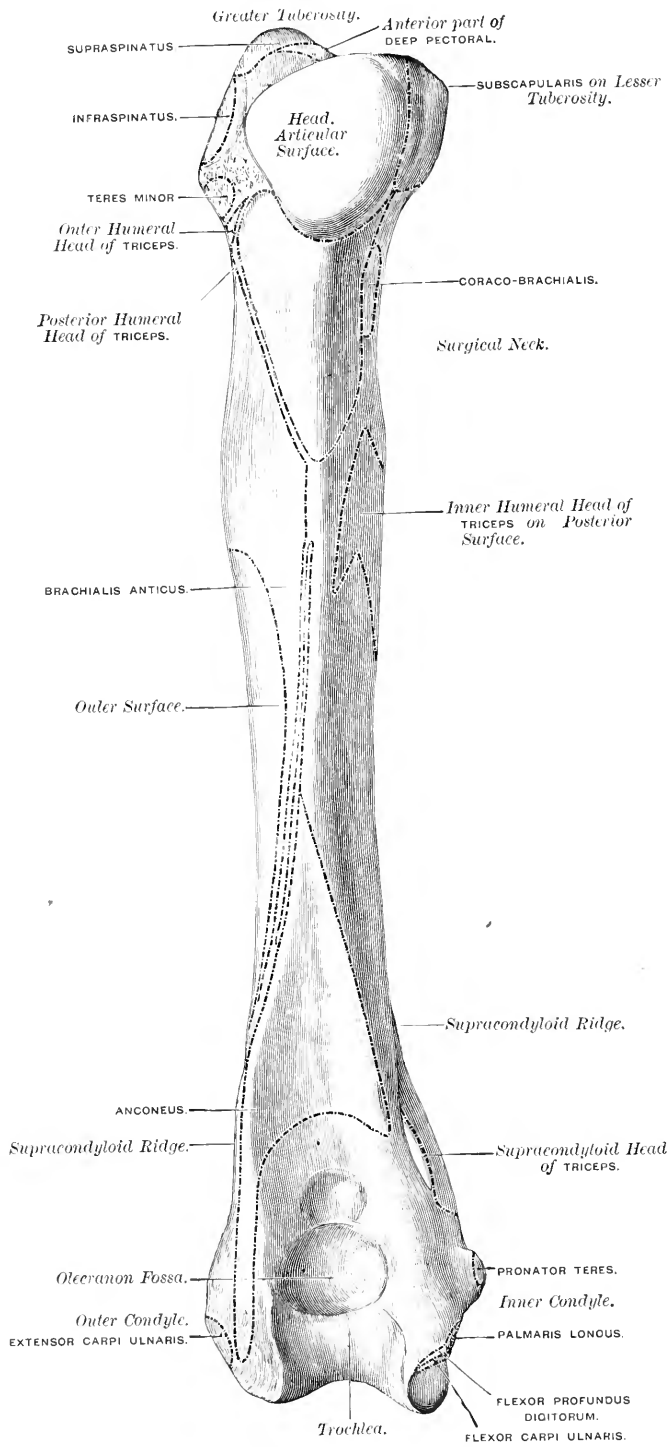
Above the inner condyle is the **supracondyloid foramen**, which, strictly speaking, is a canal piercing the side of the bone obliquely from behind, forward, downward, and inward. The bridge of bone limiting it laterally is known as the **internal supracondyloid ridge**. The canal itself is twice as high vertically as it is wide transversely. Its length from before backward is equal to its height. Its outer wall is considerably shorter than the inner wall. The relation of the greatest width to the greatest antero-posterior length varies, but averages as seventy-five is to forty-five.

The greatest antero-posterior diameter of the lower extremity is through the outer part of the articular eminence, and exceeds but slightly the same diameter at the inner end of the eminence. The anterior surface of the articular eminence lies in front of the rest of the lower extremity and the anterior surface of the shaft, and its posterior surface lies in front of the posterior surface of the extremity and of the shaft.

The **inner condyle** is an oblong tuberosity projecting outward and slightly backward from the posterior part of the inner end of the lower extremity. It has the appearance of a downward prolongation of the side of the shaft, applied to the inner end of the articular mass. For facility of study it may be said to have four surfaces.

The **anterior surface** (Fig. 430) is the continuation of the smooth terminal part of the internal surface of the shaft, bridging the supracondyloid foramen. It is bounded on the median side by the anterior supratrochlear fossa and the vertical end of the articular eminence, on the inner side by the edge which it makes with the posterior surface,

FIG. 431.



LEFT HUMERUS, POSTERIOR ASPECT.

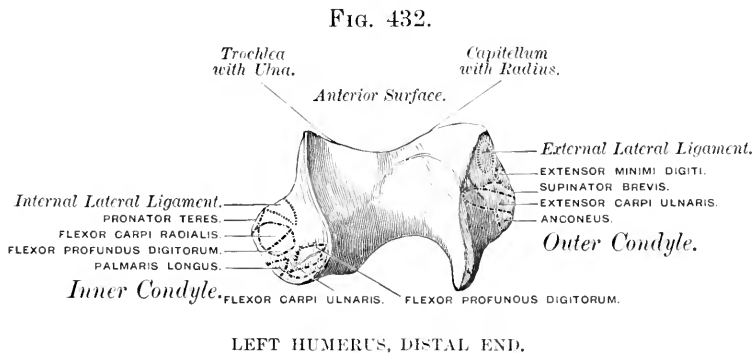


and below by the internal and inferior surfaces. It is flat, and faces forward and inward. It has no muscular attachments.

The **posterior surface** (Fig. 431) is the continuation of the posterior surface of the shaft downward and inward below the supracondylar foramen, round the olecranon fossa and the inner end of the posterior articular surface. It is smooth and almost straight from above downward, except on the inner side of its termination below, where it is slightly convex. It is gently convex from side to side. It is free from muscular attachment.

The **internal surface** (Fig. 429) is a small roughened area at the meeting of the posterior, anterior, and inferior surfaces. Its long axis is directed downward and backward. It faces inward and downward. This surface and the inferior surface give attachment to a number of muscles, but the facets for their attachment are not always clearly marked. Its superior point presents the greatest elevation of the condyle from the articular mass. It is a small, rounded projection, to which is attached the origin of the pronator radii teres. Below this prominence is a transverse depression for some of the fibres of the internal lateral ligament. Below this again is a crescentic facet for the attachment of the flexor carpi radialis and one part of the flexor profundus digitorum. Behind this facet, often separated from it by a sharp line, is another larger crescentic facet for the palmaris longus.

The **inferior surface** (Fig. 432) is a narrow strip lying between the side of the articular mass and the internal surface, and below the



anterior surface; its plane is almost at right angles with these parts, facing downward, forward, and slightly outward. Its lower boundary forms a sharp edge with the lower boundary of the posterior surface; it forms, above, a slight angle with the anterior surface. Its long axis

is directed from above downward and inward. It is slightly convex from above downward. On well-marked bones it shows above, within, and below the superior prominence of the internal surface the continuation medially of the transverse depression for the internal lateral ligament. Below this depression is a deep transverse pit for the origin of part of the humeral head of the flexor profundus digitorum muscle. Below this again, limited behind by the lower sharp edge of the surface itself, is a second equally well marked transverse pit for the origin of the humeral head of the flexor carpi ulnaris muscle.

The **outer condyle** is much simpler and less prominent than the inner. It presents anterior and posterior surfaces.

The **anterior surface** (Fig. 430) is small and narrow, and is the continuation downward of the external surface of the shaft; its upper part lies between the supracondyloid ridge and the supratrochlear fossa; it ends in a point below where the supracondyloid ridge meets the outer end of the articular eminence. It affords origin to the extensor carpi radialis brevis and extensor communis digitorum muscles.

The **posterior surface** (Fig. 431) of the outer condyle is the continuation of the posterior surface of the shaft downward, round the olecranon fossa and the articular eminence. It is narrower above than below, where it terminates in a rough line against the side of the articular eminence. It is convex from above downward and slightly convex from side to side. Its lower part is marked, just without the sharp edge of the articular eminence, by a more or less developed longitudinal depression. The posterior surface affords attachment to the following muscles: on its inner side, to the anconeus; on the border which it makes with the anterior surface, to the extensor communis digitorum; on the inferior line of junction with the articular eminence, in the following order from above downward, to the extensor minimi digiti, the supinator brevis, and the extensor carpi ulnaris. In the deep pit on the side of the articular eminence, in front of this line, is inserted the external lateral ligament of the elbow-joint.

The **articular eminence** on the lower extremity of the humerus is a spool-shaped mass extending transversely between the condyles. As it articulates with both bones of the forearm, it presents a surface for the end of each bone. That for the radius is known as the **capitellum**, or smaller head of the humerus; it forms the outer half of the anterior aspect of the general articular surface, and ends in a point

below. It is limited, on the outer side, by a rounded border; above, it meets the anterior surface of the extremity at a right angle; on the median line, it passes into the articular surface for the ulna. It is strongly convex from above downward and slightly convex from side to side, and is received into the shallow oval articular surface on the head of the radius.

The articular surface for the ulna is known as the *trochlea*.<sup>1</sup> It differs from the capitellum in being convex from above downward and concave from side to side. It is limited on the inside, in front and below, by a sharp crest, and behind by a groove which separates it from the posterior surface of the inner condyle. It is limited on the outside, at the back, by the sharp crest which forms the inner margin of the posterior surface of the outer condyle; below and in front the outer side is continuous with the capitellum. The articular surface is covered with a layer of cartilage, and is received into the greater sigmoid cavity of the ulna.

Above the capitellum the anterior surface of the lower extremity is marked by an oval depression for the edge of the head of the radius in extreme flexion of the forearm, and above the trochlea is a similar depression for the coronoid process of the ulna. On the posterior surface of the extremity, above the trochlea, is a very large, deep pit, bounded laterally by the edges of the posterior surfaces of the condyles, and becoming gradually shallow as it ascends the shaft. The lower part of the pit receives the superior lip of the sigmoid cavity in extreme extension of the forearm. There is often a second oval depression above this lower part, which receives the end of the olecranon process. The capsular ligament of the elbow-joint is attached to the lower extremity at the borders of the articular eminence.

**Nomenclature.**—The *humerus* of the Romans was the whole shoulder, including both flesh and bones. The three bones which support it were known as *ossa humeri*, each as an *os humeri*. The term *os humeri* was gradually restricted to the one bone of the upper arm, and then the bone itself was called *humerus*. As synonyms we find *os humeri* and *os brachii*. The German word is *das Oberarmbein*, the French, *l'humérus*.

**Determination.**—If the humerus be held with the anterior surface

<sup>1</sup> From *trochilia* (Gr.), a pulley.

FIG. 433.

*At Thirty Days.**At Seventy Days.**At One Hundred and  
Thirteen Days.*POSTERIOR  
ASPECT.ANTERIOR  
ASPECT.PLAN OF THE DEVELOPMENT OF THE  
HUMERUS FROM SEVEN CENTRES.

(Natural size.)

uppermost and the lower end toward the student, the supracondyloid foramen will be on the side to which the bone belongs.

**Articulation.**—The humerus articulates with the scapula, the radius, and the ulna.

**Muscular Attachments.**—The following muscles are inserted on the humerus: on the greater tuberosity, the *supraspinatus*, the anterior part of the *deep pectoral*, the *infraspinatus*, and the *teres minor*; on the lesser tuberosity, the *subscapularis*; on the anterior border, the posterior part of the *deep pectoral*, the *middle pectoral*, the anterior part of the *middle pectoral*, the *superficial pectoral*; on the deltoid ridge, the outer humeral head of the *triceps*; on the external surface and deltoid ridge, the *deltoid*; on the anterior border and the external surface, the anterior part of the *middle pectoral*; on the internal surface, the *teres major* and the *latissimus dorsi*; on the internal border, the *coraco-brachialis* and the supracondyloid head of the *triceps*.

The following muscles arise from the humerus: on the external and posterior surfaces, the posterior humeral head of the *triceps*; on the external surface, the *brachialis anticus*; on the posterior surface, the inner humeral head of the *triceps* and the *anconeus*; on the

inner condyle, the pronator teres, the flexor carpi radialis, the flexor profundus digitorum, the palmaris longus, and the flexor carpi ulnaris; on the posterior border and the external supracondyloid ridge, the supinator longus, the extensores carpi radialis longior and brevior and communis digitorum; on the outer condyle, the extensores minimi digiti and carpi ulnaris and the supinator brevis.

**Blood Supply.**—The nutrient artery for the shaft of the humerus arises from the brachial artery in the lower third of the arm, a little above the supracondyloid foramen, often in common with a large muscular branch for the biceps muscle.

**Ossification.**—The humerus is developed from seven centres of ossification,—namely, for the shaft, for the head and greater tuberosity, for the capitellum, for the trochlea, for the inner condyle, for the outer condyle, and for the lesser tuberosity.

At birth the shaft is already ossified, and a small centre is visible in the upper extremity. At thirty days the upper extremity is largely ossified, and the lower extremity, which is still almost entirely cartilaginous, exhibits a large centre for the capitellum and a small centre for the trochlea. At forty-four days there is a centre of good size on the back of the inner condyle, and a very small centre has appeared in the outer part of the outer condyle. At sixty days the lesser tuberosity exhibits a distinct centre. At one hundred and thirteen days the centre in the outer condyle has coalesced with the capitellum, which has joined the trochlea.

#### VARIATIONS IN THE HUMERUS.

##### VARIATIONS IN SIZE.

The measurements of the humerus are taken as follows:

The maximum length is the distance on the long axis from the top of the greater tuberosity to the most projecting point of the inner edge of the lower articular eminence.

The width at the upper end is the greatest transverse diameter from tuberosity to tuberosity.

The height at the upper end is the antero-posterior diameter from the anterior border to the posterior most projecting point of the articular surface of the head.

The width at the condyles is the maximum transverse diameter.

The height at the condyles is the greatest antero-posterior diameter measured with sliding calipers.

Side.	Maximum length.	Width at upper end.	Width at condyles.	Height at upper end.	Height at condyles.
Right . . . . .	83	15	17	18.5	9.5
Left . . . . .	84	15	17.5	18.5	9.5
Left . . . . .	84.5	15	16.5	18	9.5
Right . . . . .	85	14	15.5	17.5	10
Right . . . . .	85	14.5	16	18	14
Left . . . . .	85	15	16	18	9
Right . . . . .	85	15	16.5	19	9.5
Right . . . . .	85.5	13	16.5	18.5	9
Left . . . . .	86	15	17	19	10
Right . . . . .	86	16.5	19	20	11
Left . . . . .	86.5	14.5	17	18.5	9.5
Right . . . . .	87	14	17	18.5	10
Right . . . . .	87	14.5	17	18.5	9.5
Right . . . . .	87	15	16.5	17.5	9.5
Left . . . . .	87	15	16.5	17.5	9.5
Right . . . . .	87	16	18	19.5	10.5
Right . . . . .	87	15.5	17.5	20	10.5
Right . . . . .	87	17	18	20	10
Left . . . . .	87	17	18.5	20	10
Left . . . . .	88	14.5	17	19	10
Left . . . . .	88	15	18	19	10
Right . . . . .	89	14	16	18	10
Left . . . . .	90	15	18	19.5	10.5
Left . . . . .	90	15.5	18	21	11
Left . . . . .	90	15.5	18	20	10
Left . . . . .	91	13.5	17	19	9.5
Left . . . . .	91	15	17	19	9.5
Left . . . . .	91	15	17.5	18.5	9.5
Right . . . . .	91	15	17	18.5	10
Right . . . . .	91	15.5	17.5	20	10
Left . . . . .	91	15.5	18	20	10
Left . . . . .	91	16	17.5	20	10
Right . . . . .	91	17	18.5	21	11
Right . . . . .	92	14	17	19	10
Right . . . . .	92	15	17.5	20	10.5
Left . . . . .	92	17	18.5	21	11
Right . . . . .	92.5	16	18	21	10
Left . . . . .	93	15	17.5	20	10
Right . . . . .	93	15.5	18	19	10
Left . . . . .	93	16	18	19.5	10
Right . . . . .	93	17.5	19	21	11
Right . . . . .	93.5	15.5	18	20	10.5
Left . . . . .	95	15	18	19	9.5
Right . . . . .	95	15	18.5	20	10.5
Left . . . . .	95	16.5	19	21	11
Right . . . . .	95.5	15	18.5	20	10.5
Left . . . . .	96	16	18.5	20	10.5
Right . . . . .	96	16.5	19	21	11
Left . . . . .	96	17	19	21	10.5
Right . . . . .	97	16	19.5	21.5	11
Left . . . . .	97	17	19.5	21.5	11
Right . . . . .	98	16	19.5	22	11
Left . . . . .	98	17	20.5	22.5	11
Right . . . . .	98.5	17	19	22	11
Left . . . . .	99	17	19.5	22.5	11.5
Right . . . . .	100	18	20.5	22	12
Right . . . . .	100	16	19.5	21	11
Left . . . . .	100	18	20	22	12
Left . . . . .	100	18	20	22	11.5
Right . . . . .	100.5	18	20	23	11.5
Right . . . . .	104	16.5	20.5	22.5	11.5
Left . . . . .	104	16.5	20	22	11.5
Left . . . . .	104	17.5	19.5	23	12
Right . . . . .	104	19	20	23.5	12
Right . . . . .	105	17	19	21.5	11.5
Left . . . . .	105	18	21	23.5	12
Right . . . . .	106	18	21	23.5	12
Right . . . . .	106	18	21	23.5	12.5
Right . . . . .	107	19	20.5	23	11.5
Left . . . . .	107.5	19	20.5	23	11.5

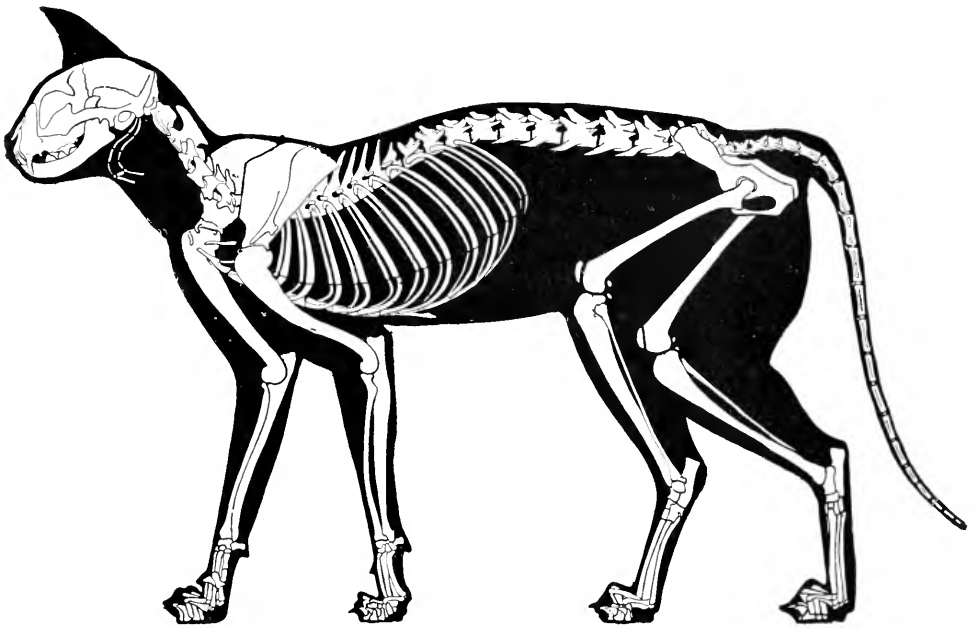
## VARIATIONS IN FORM AND DEVELOPMENT.

The greater tuberosity exhibits variations in its height above the articular surface of the head.

The deltoid ridge is occasionally very prominent; it is usually moderately well developed; it may be entirely absent. In some specimens the area of attachment of the tendon of the *teres major* and *latissimus dorsi* muscle is elevated into a strong crest. Rarely the upper limit of the area of origin of the *brachialis anticus* muscle on the external surface is indicated by an oblique line passing from the deltoid ridge downward and backward to the external border.

The supracondyloid foramen varies in size and shape; in some specimens it is long and narrow, in others it is short and broad. It is never absent.

FIG. 434.



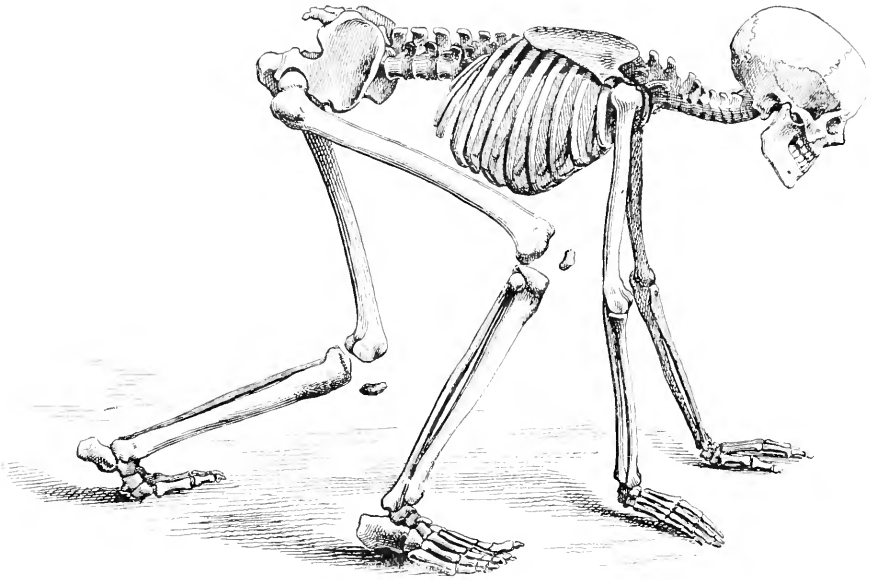
THE SKELETON OF THE CAT.

I have seen no cases of perforation of the lamina between the supratrochlear and the olecranon fossa.

The student should observe the striking difference in general appearance which is exhibited by the long bones of different cats; some are smooth, dense, and delicately moulded, although all the processes and muscular lines may be strongly developed; others are fashioned more rudely and are rougher and more porous. The former

class of bones appear to belong to animals of a finer breed, or to those which have been better cared for. These are not sexual differences, nor are they dependent upon age.

FIG. 435.



HUMAN SKELETON IN THE POSTURE OF THE SKELETON OF THE CAT.

### HUMAN HUMERUS.

The humerus is the longest bone in the human thoracic limb, hence the arm is longer than the forearm; in the cat the ulna is longer than the humerus, hence the forearm is longer than the arm (Figs. 434, 435). As compared with the cat's humerus, the human bone is more slender and the extremities are more clearly defined from the shaft. A constriction, the **surgical neck**, separates the shaft from the rounded mass formed by the head and the two tuberosities.

The **head** is a section of a sphere, and its smooth articular surface is limited by a line which marks the **anatomical neck**. When the bone is held with the internal epicondyle uppermost, the articular surface of the head is also uppermost; when the cat's bone is so held, the articular surface is at the side. In man the humerus hangs at right angles to the scapula; in the cat it is approximately in the same dorso-ventral plane.

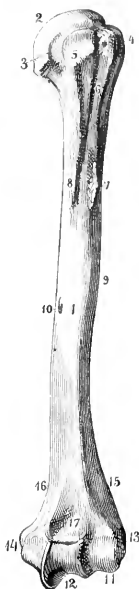
The **greater tuberosity** in the human humerus is more rounded and less conspicuous than the corresponding prominence in the cat. It is marked by three facets, for the insertion from above downward of the supraspinatus, infraspinatus, and teres minor muscles.



The bicipital groove is narrow, and its lips, or bicipital ridges, are prominent; to the outer lip is attached the pectoralis major muscle; to the inner lip the latissimus dorsi and teres major muscles. In a fossa at the upper end of the groove, the *fovea capitis*, is inserted the glenohumeral ligament. The lesser tuberosity is more prominent than in the cat. On a smooth space on its upper surface is inserted the subscapularis muscle.

The shaft is cylindrical above, but flattened from before backward below. The inner aspect is crossed from behind downward and forward by a wide musculo-spiral groove for the musculo-spiral nerve and the deep brachial vessels. The oblique disposition of these structures and the different planes of the articular extremities are the results of a torsion of thirty degrees which has taken place in the humerus round its long axis during development. The shaft presents three borders, anterior, external, and internal, and three surfaces, external, internal, and posterior. The anterior border runs downward from the outer lip of the bicipital groove and ends between the capitellum and the trochlea. The external border extends from the posterior border of the greater tuberosity to the outer condyle. It is crossed by the musculo-spiral groove; its lower end is termed the **external supracondyloid ridge**. The internal border begins above as the inner lip of the bicipital groove and ends as the **internal supracondyloid ridge**. At its middle it is roughened for the insertion of the coraco-brachialis muscle. Below this area is the nutrient foramen. The external surface lies between the anterior and external borders. Above the middle is the rough deltoid ridge, and below it the musculo-spiral groove. The internal surface (sometimes called the anterior surface) is between the anterior and internal borders. Its upper part is the bicipital groove; from its lower part arises the brachialis anticus muscle. The posterior surface is between the internal and external borders. It is smooth;

FIG. 436.



LEFT HUMERUS. VIEWED IN FRONT.

1, shaft; 2, head; 3, neck; 4, greater tuberosity; 5, lesser tuberosity; 6, bicipital groove; 7, 8, ridges bounding the latter and giving attachment to muscles; 9, position of insertion of the deltoid muscle; 10, principal nutrient foramen; 11, capitellum for the radius; 12, trochlea for the ulna; 13, 14, external and internal epicondyles; 15, 16, supracondyloid ridges; 17, fossa for the coronoid process of the ulna.

the part above the musculo-spiral groove gives origin to the external head of the triceps muscle, and the larger part below the groove to the internal head of the same muscle.

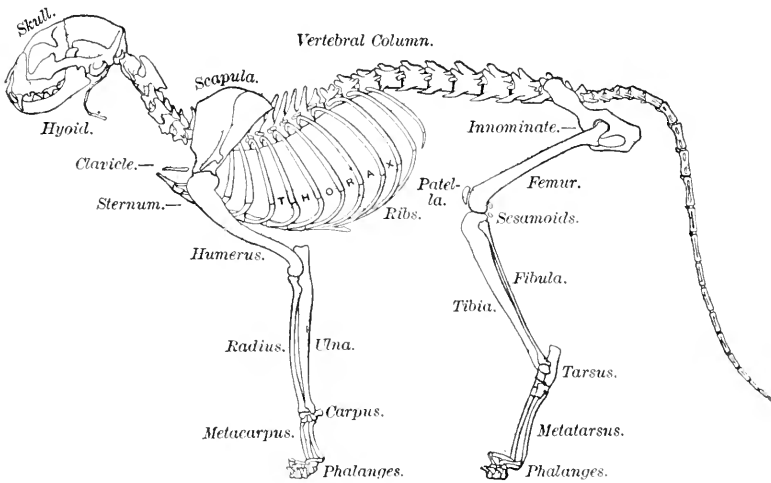
The human humerus normally has no supracondyloid foramen.

The lower extremity presents only a few differences. The capitellum is more clearly defined from the trochlea; the articular eminence is not so deeply concave transversely; the internal epicondyle is more prominent.

### THE ULNA.

**General Description.**—The Ulna is about a seventh longer than its companion the radius. It is the longest bone in the thoracic extremity, and, with the exception of the tibia, is the longest bone in the entire skeleton. It lies at the back of the forearm, on the inner

FIG. 437.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

side, and can be felt through the skin and muscles (Fig. 437). When the palm of the hand is turned to face forward and inward, the radius is on the outer side of the ulna and parallel with it; but in the usual position of the hand, with the palm partly on the ground and partly facing backward, the radius is in front of the ulna, except for a small distance at its upper end. The ulna articulates by its upper end with the trochlea of the humerus, and by its lower end with two of the bones of the wrist, the cuneiform and the pisiform. It articulates by both ends with the contiguous ends of the radius. It is a narrow, slender bone, whereof the long diameter is ten or eleven times greater

than the greatest antero-posterior diameter, which is at the proximal extremity. The greatest transverse diameter is also at the proximal extremity, and is a little more than half the greatest antero-posterior diameter. The smallest diameters are the transverse, at the junction of the proximal and middle thirds of the bone, and the antero-posterior, near the distal end. The ulna presents for examination a large proximal or upper extremity, a long, slender shaft, and an unimportant distal or lower extremity.

The **Upper Extremity** of the ulna (Fig. 438) comprises the upper fifth of the bone, and embraces the region of its greatest diameters. It is a quadrate mass with parallel lateral surfaces and parallel anterior and posterior surfaces and a proximal surface which is in the main level. Its transverse diameter is but half its antero-posterior diameter. The upper extremity is bent inward, somewhat away from the long axis of the bone. It is deeply excavated in front by the **greater sigmoid**<sup>1</sup> cavity, whereof the lowest point is on the imaginary transverse line which forms the artificial lower boundary of the extremity. The region proximal to the middle of the sigmoid cavity is known as the **olecranon**<sup>2</sup> process of the ulna.

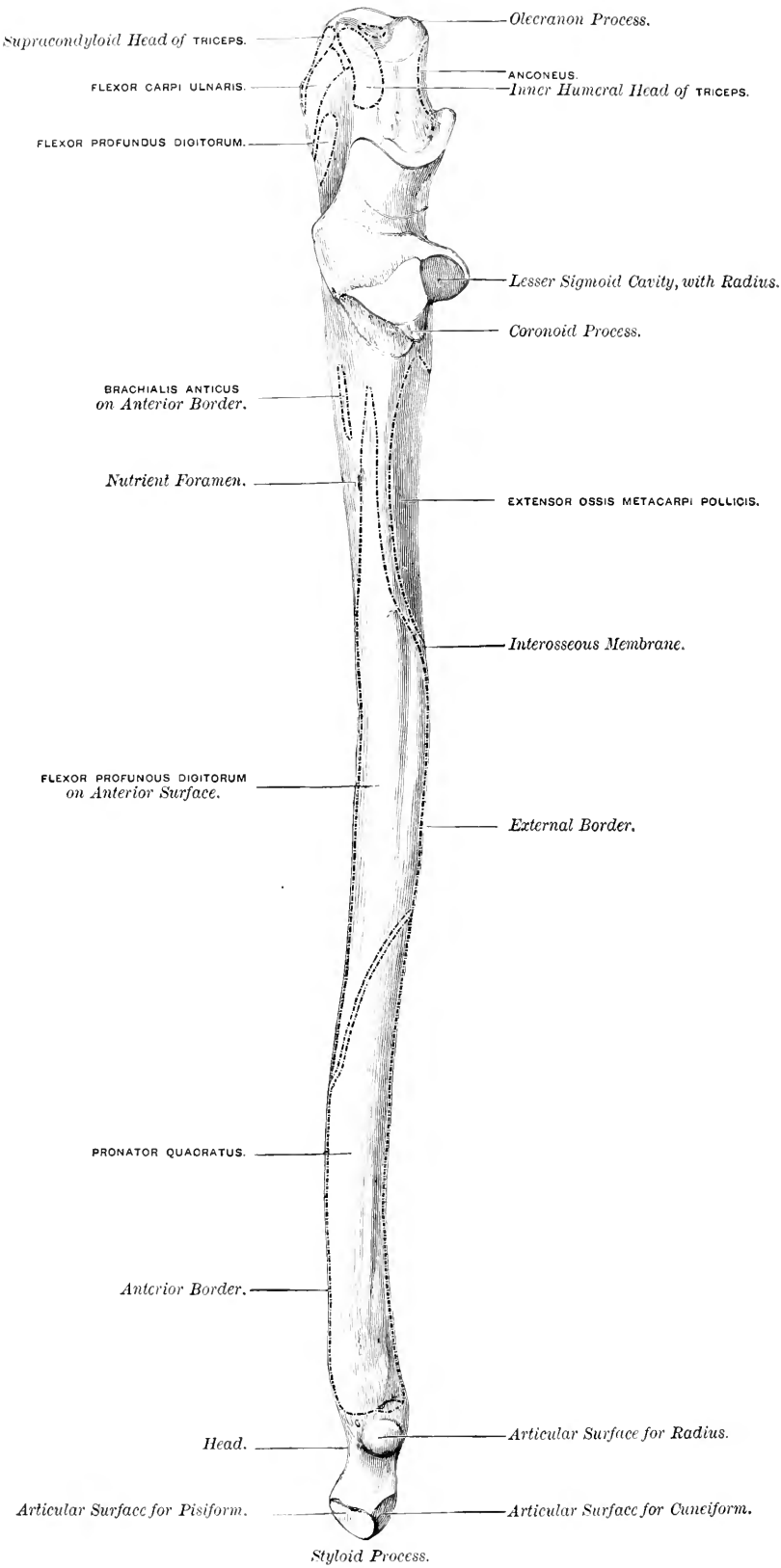
The **anterior surface** of the upper extremity is divided into two parts, the upper and smaller of which forms also the anterior surface of the olecranon process, and the lower and larger part is occupied by the sigmoid cavity. The upper part is twice as long as it is wide, and the long axis is directed obliquely to the long axis of the shaft from above outward and downward. Its proximal border, emarginated by the anterior end of the antero-posterior groove on the proximal surface, is thin and sharp on the inner side and rounded and swollen on the outer side. The lateral margins are also emarginate, but to a less degree. The distal or lower margin is arcuate, sharp, and more or less elevated, and forms the upper edge of the sigmoid cavity. The surface itself is gently saddle-shaped, convex from side to side, and concave from above downward. The inner margin forms part of the area of insertion of the inner humeral head of the triceps muscle; to the outer margin is attached part of the anconeus. The proximal and distal margins afford attachment to fibres of the capsular ligaments.

The **proximal surface** of the ulna (Fig. 439), also the proximal

<sup>1</sup> From its likeness to the Greek letter *sigma*, which in its old form resembles a C.

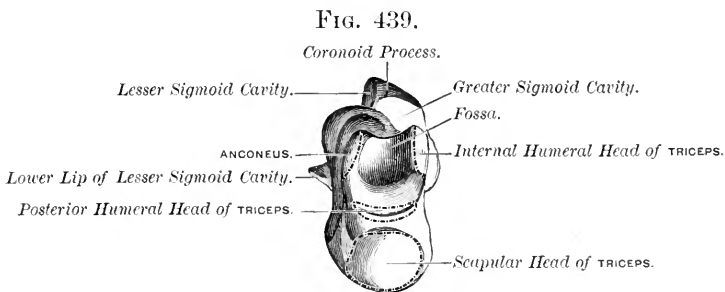
<sup>2</sup> From (Gr.) *olene*, the elbow, and *kranion*, the head.

FIG. 438.



LEFT ULNA, ANTERIOR SURFACE.

surface of the olecranon, is quadrate, and twice as long as wide. It is slightly wider in front than behind, and at about its middle it is impressed by a transverse crescentic line. The region anterior to this line is quadrate and deeply concave from side to side. The anterior margin is depressed and emarginate; the lateral margins are prominent and rounded. The internal humeral part of the triceps is attached to the anterior part of the inner margin, and the anconeus to the anterior part of the outer margin. The crescentic line which forms the posterior boundary of this excavation affords attachment to the posterior humeral part of the triceps. This excavated anterior part of the proximal surface of the ulna is occupied by a mass of fat, forming a cushion, over which passes the tendon of the triceps muscle. Behind the crescentic groove the proximal surface is swollen and convex, and passes without a distinct margin into the posterior surface of the upper



THE ULNA, PROXIMAL SURFACE OF OLECRANON PROCESS.

extremity. It forms the prominent part of the elbow, and to it is attached the tendon of insertion of the scapular part of the triceps.

The **posterior surface** of the upper extremity of the ulna is triangular (Fig. 441), having the width of the proximal surface above, and passing below into the posterior border of the shaft. Its lateral margins are distinct; the inner is sharp and prominent above and rounded below; the outer is less distinct above and sharper and more prominent below. The outer margin, moreover, is continued downward as the posterior border of the shaft. This posterior surface is smooth and convex from side to side, and from above downward flat or slightly concave in its upper part and gently convex in its lower part. It faces outward and backward.

The **internal surface** of the upper extremity (Fig. 442) presents an almost square, slightly concave portion above, and a narrower portion below and behind the sigmoid cavity. This latter region is impressed

FIG. 440.

*Posterior Humeral Head of TRICEPS.*

*Olecranon Process.*

*ANCONEUS.*

*Scapular Head of TRICEPS*

*Outer Humeral Head of TRICEPS.*

*Greater Sigmoid Cavity.*

*With Head of Radius.*

*Lesser Sigmoid Cavity.*

*Coronoid Process.*

*EXTENSOR CARPI ULNARIS.*

*Posterior Border.*

*Posterior Surface.*

*EXTENSOR INDICIS.*

*FLEXOR PROFUNDUS DIGITORUM.*

*Shaft.*

*External Border.*

*EXTENSOR OSSIS METACARPI POLLICIS*

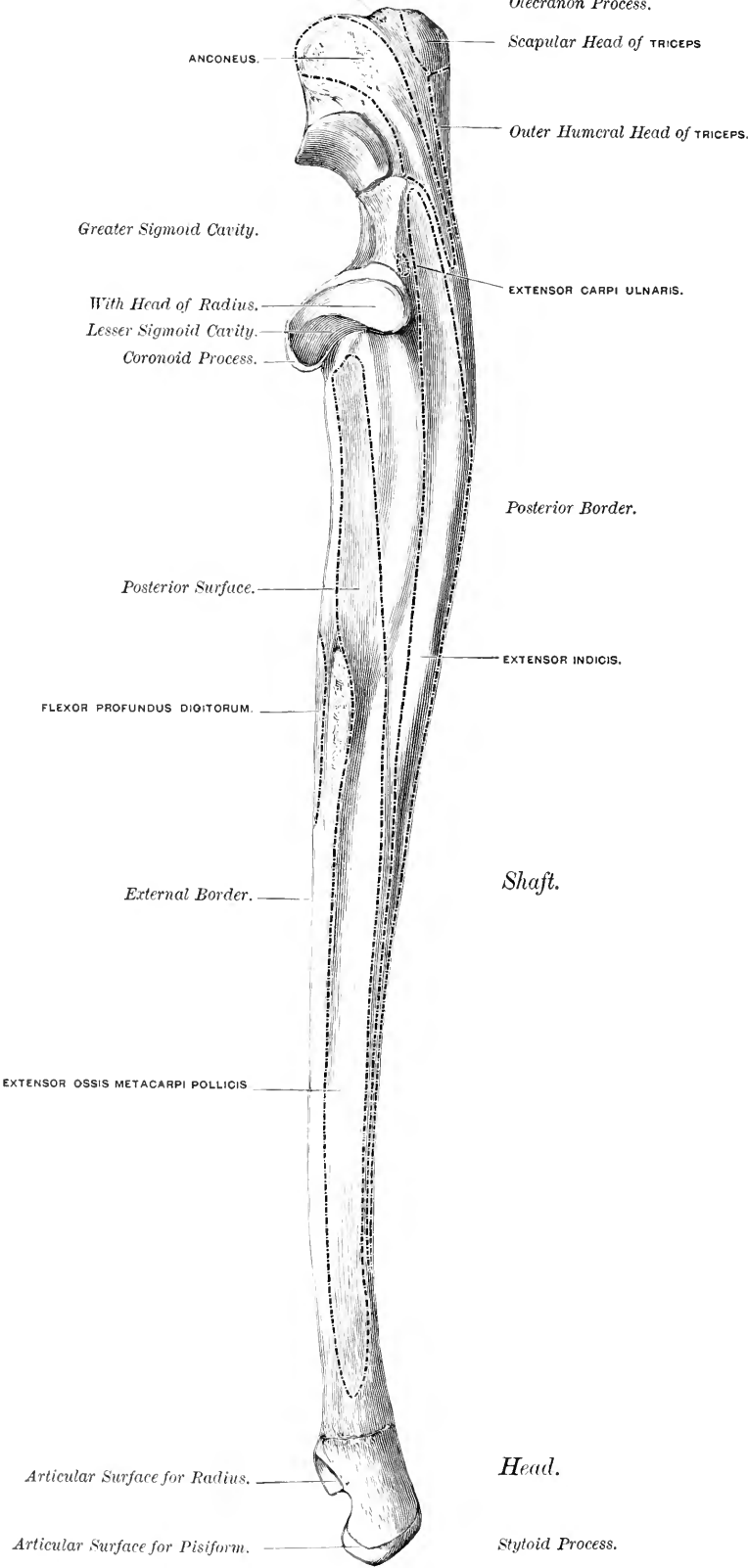
*Head.*

*Articular Surface for Radius.*

*Articular Surface for Pisiform.*

*Styloid Process.*

LEFT ULNA, OUTER OR RADIAL ASPECT.



by a shallow longitudinal groove, from which arise the upper fibres of the ulnar head of the flexor profundus digitorum muscle. The inner humeral head of the triceps muscle is inserted on the outer margin and the contiguous region of the surface, and the supracondyloid head of the same muscle is inserted close to the proximal and prominent posterior margins. Just anterior to this last area of insertion and curving for a distance downward on the inside of the posterior margin is the area of origin of the ulnar head of the flexor carpi ulnaris muscle. A small roughened area behind the lower part of the sigmoid cavity marks the point of attachment of the lateral ligament of the elbow-joint.

The **external** or **radial surface** (Fig. 440) of the upper extremity has the same shape as the internal surface. Its upper part is slightly excavated, and behind is somewhat encroached upon by the posterior surface. Its lowest part is deeply concave, the concavity beginning opposite the middle of the sigmoid cavity and flattening out on the shaft below. The anconeus muscle is inserted on most of the upper part, and the scapular and outer humeral head of the triceps along the posterior margin. The upper part of the extensor indicis springs from the groove on the lower part. On the anterior edge of this groove, a little below the middle of the sigmoid cavity, is a small point of origin for fibres of the extensor carpi ulnaris muscle.

The **greater sigmoid cavity** is a deep semicircular emargination on the anterior surface of the upper extremity of the ulna. It is twice as long as wide, and narrower above than below. Its long axis is directed downward and inward, and it therefore forms a small angle with the long axis of the upper extremity, which runs downward and outward, and is also somewhat oblique to the long axis of the bone itself. The upper margin of the cavity is arcuate and sharp. The lower margin is irregular; its outer half is occupied by the crescentic articular cavity for the head of the radius known as the **lesser sigmoid cavity**. On the outer side of this cavity the margin is produced into a pyramidal **coronoid process**. The greater sigmoid cavity is convex from side to side, and is distinctly marked off by the smoothness and density of its surface from the lateral surfaces of the bone itself. It is divided in the middle by the transverse band, more or less broad, which marks the lower boundary of the olecranon and separates the superior and inferior articular surfaces, which are covered with cartilage and move upon the trochlea of the humerus.

The **lesser sigmoid cavity** is concave transversely, and is shallower than the greater sigmoid cavity. It faces outward. Its long diameter is almost transverse to the long axis of the ulna, passing backward and somewhat proximally, and is three times greater than the proximo-distal diameter. The rounded outer end of the cavity is supported by a prominent lip for ligamentous attachment, the posterior surface of which overhangs the groove for the extensor indicis muscle. The inner anterior end is pointed and forms the outer surface of the coronoid process. The upper and lower margins of the cavity are parallel; the upper slightly arcuate, the lower faintly emarginate at the middle. The lesser sigmoid cavity receives the anterior side of the head of the radius and permits of some rotatory motion.

The **coronoid process** is a small pyramid, the apex of which points outward, downward, and forward when the bone is held vertically. Its sharp anterior border separates the outer surface belonging to the lesser sigmoid cavity from a smooth, triangular, gently convex anterior surface, which faces forward, inward, and upward, is covered with articular cartilage, and enters into the elbow-joint. The triangular posterior surface of the coronoid process is rough for the attachment of the capsular ligament of the articulation, and is marked at its base by a transverse groove for the internal lateral ligament from the humerus.

The **Shaft** of the ulna comprises almost the entire bone. In the proximal third it is compressed from side to side, but is deep from before backward; in the lower two-thirds it is triangular on cross section. Its antero-posterior diameter becomes less toward the inferior extremity. From above downward the shaft is bowed slightly forward; it has a sinuous curve from side to side, at first bending from the superior extremity outward at the middle point, then it gradually turns and at the lower end is again directed slightly outward. Three surfaces, the anterior, the internal, and the posterior, and three borders, the external, the anterior, and the posterior, may be distinguished on the shaft of the ulna.

The **anterior border** (Fig. 442) begins above on the inner side of the greater sigmoid cavity, at the roughened area of attachment of the internal lateral ligament; it follows the curves on the bone and ends on the inner side of the lower extremity. The border is not distinct in its proximal two-thirds, where it rather represents the maximum con-



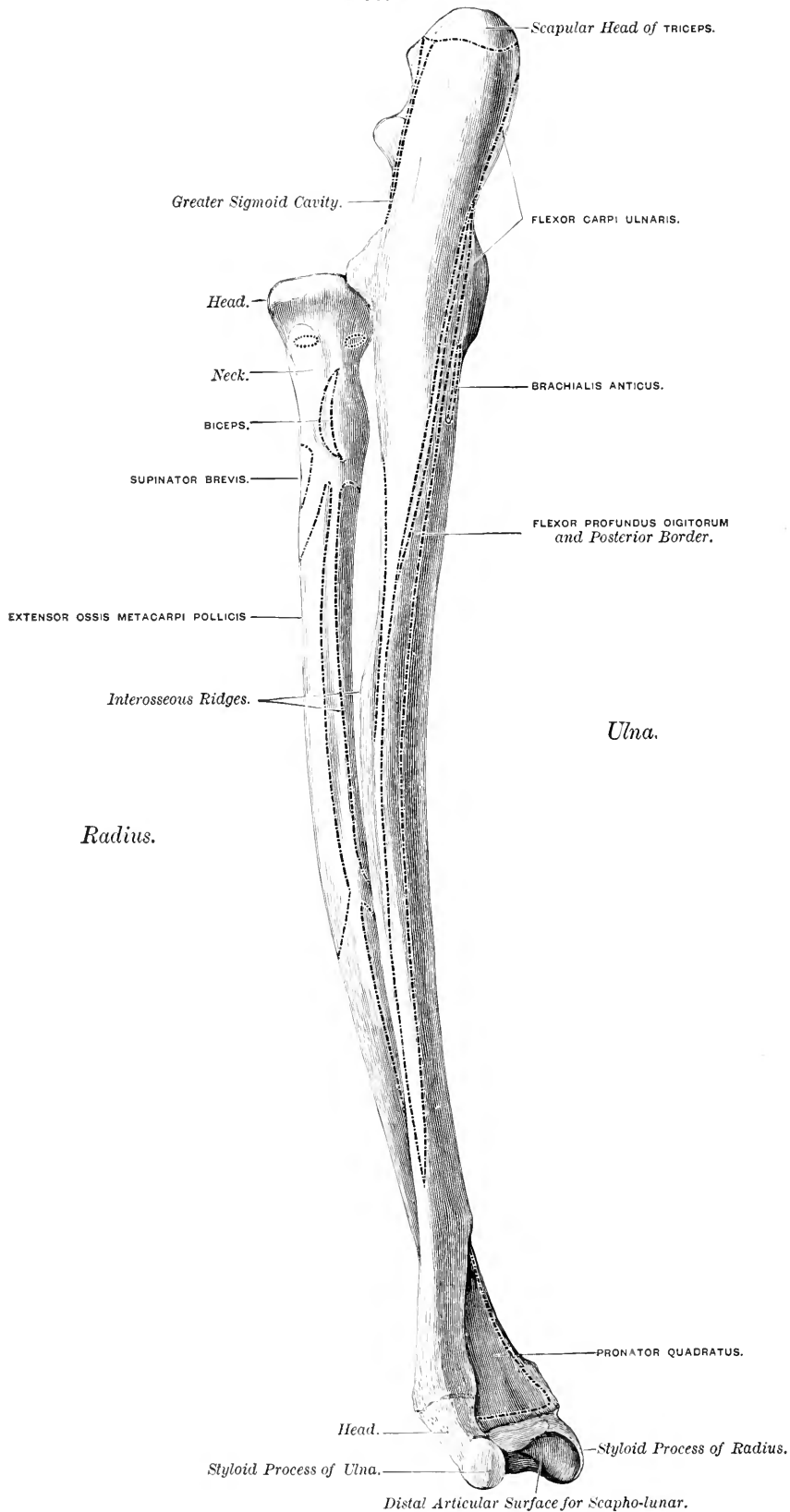
vexity of the inner aspect of the bone, but in the lower third it becomes prominent and sharp. It forms the inner boundary of the area of attachment of the radio-ulnar head of the flexor profundus digitorum and pronator quadratus muscles. On it, or just anterior to it, at a distance of about ten millimetres below the base of the coronoid process, is the nutrient foramen of the shaft, which pierces the compact tissue obliquely toward the upper extremity. The **anterior border** separates the anterior and internal surfaces; in walking it faces inward.

The **posterior border** (Fig. 441) begins above as the prolongation of the posterior surface of the olecranon, and is continued without interruption to the back of the lower extremity. It is everywhere distinct, but is more rounded above than below. It separates the areas of attachment of the ulnar heads of the flexor carpi ulnaris and flexor profundus digitorum muscles from the area of attachment of the extensor indicis. The posterior border is between the internal and posterior surfaces; it faces backward and outward.

The **external or interosseous border** (Figs. 438, 440) arises above from the coronoid process, and, passing down on the front and outer side, ends on the outer side of the lower extremity. Its smooth and rounded upper fourth separates the flexor profundus digitorum and extensor ossis metacarpi pollicis muscles. Its lower three-fourths are prominent, sharp, and, in the upper part, rough, to give attachment to the interosseous membrane connecting the ulna with the radius. This part of the border and the interosseous membrane separate the flexor profundus digitorum and pronator quadratus from the extensor ossis metacarpi pollicis muscles. The external border faces outward and forward and divides the anterior from the posterior surface.

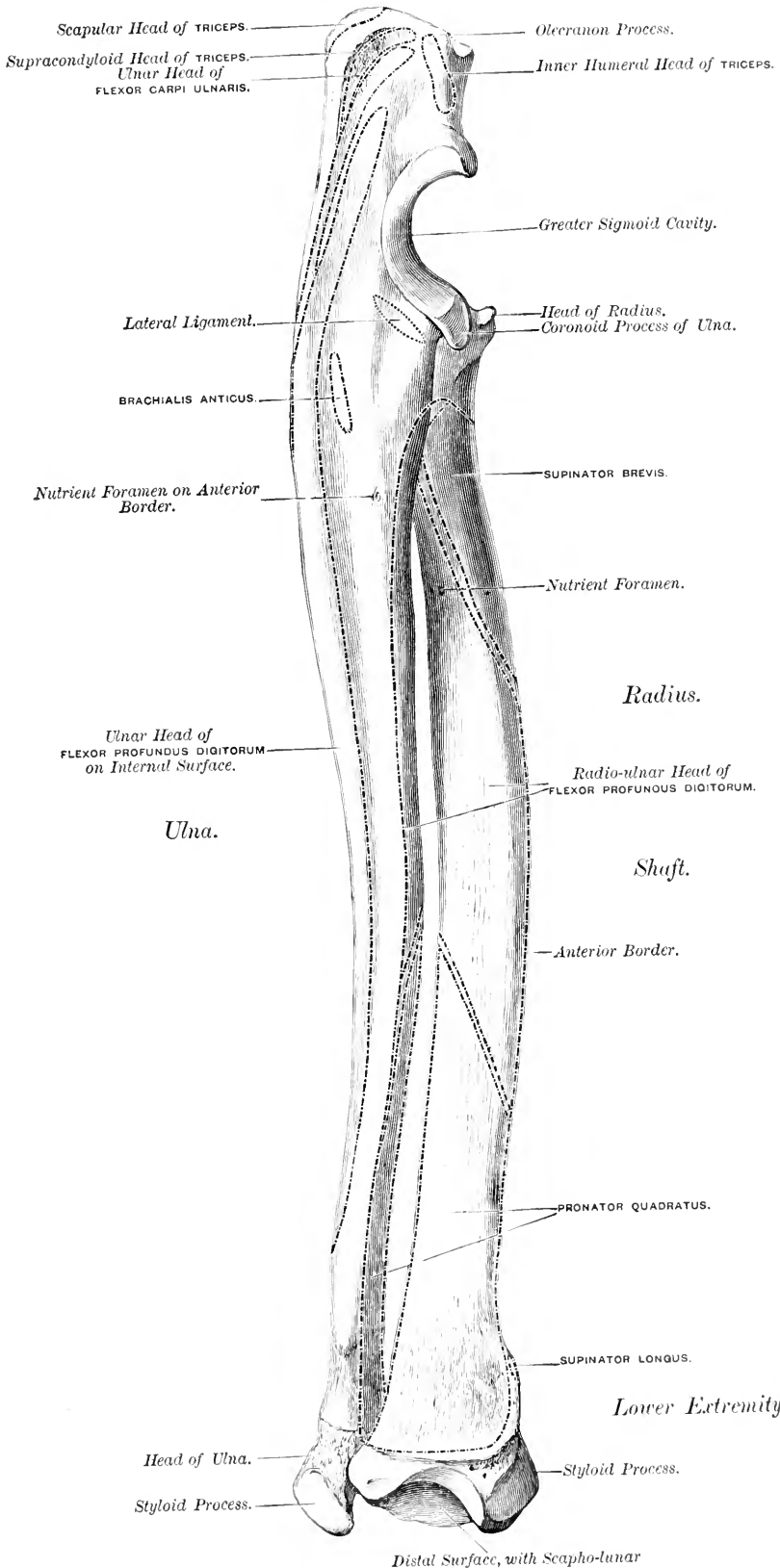
The **anterior surface** (Fig. 438) lies between the external and anterior borders. Its upper fourth is slightly narrower than the remaining portion and is convex transversely; sometimes just below the coronoid process it is elevated in the middle line almost to a ridge. Below the upper fourth, the surface becomes suddenly wider, owing to the increased prominence of the external border; it gradually becomes less convex, and in the lower third is quite flat and twisted inward. The surface faces inward and forward. Its upper part affords an area for the origin of the flexor profundus digitorum, and the lower part gives attachment to the ulnar end of the pronator quadratus.

FIG. 441.



ULNA AND RADIUS IN PRONATION, POSTERIOR ASPECT.

FIG. 442.



ULNA AND RADIUS, INNER ASPECT.

The **internal surface** (Fig. 442) is situated between the anterior and posterior borders. It is of equal width above and below, but it is so twisted on its long axis that while the upper part faces inward the lower part faces backward. The surface in the main is concave from above downward and is convex transversely; it is marked for most of its extent by a faint median groove. At its upper end is a median oblong, roughened area, into which the tendon of the brachialis anticus is inserted. The ulnar head of the flexor profundus digitorum has its origin along the posterior border.

The **posterior surface** (Fig. 440) is the largest of the three surfaces; it lies between the posterior and external borders, and occupies the entire outer aspect of the bone. At its upper end it is wide, presenting the greatest antero-posterior diameter of the bone; at the lower end it is narrow. Its anterior margin is slightly sinuous; the posterior margin is slightly emarginate. In its upper fourth it is nearly flat; a ridge, more or less marked, runs distally for a short distance from the root of the posterior lip of the lesser sigmoid cavity. The region contiguous to the external border, extending from the upper to the lower fourth, is prominent and roughened for ligamentous attachment. The remaining part of the surface is concave transversely above and convex below, and the whole surface is gently convex from the proximal to the distal end. Two muscles arise from this surface,—the extensor indicis above and behind and the extensor ossis metacarpi pollicis from the whole length, above only from the front, but below from the entire width.

The **Lower Extremity** of the ulna is small, and consists of two parts, the head and the styloid process.

The **head** is separated from the shaft by a straight roughened line running round the bone. This line is most clearly marked in front, where it forms the lower boundary of the anterior surface of the shaft. It is the remains of the suture once existing between the shaft and the distal epiphysis. The circumference of the head is scarcely larger than that of the terminal portion of the shaft. It is short in the proximo-distal line. Its outer posterior part is produced into the styloid process. The head presents anterior and posterior surfaces and external and posterior borders.

The **posterior surface** is the continuation of the posterior surface of the shaft. It is quadrate and roughened and flat or slightly convex.

Its anterior and posterior margins are directed obliquely downward and backward. The surface is continued below upon the posterior surface of the styloid process.

The **external border** of the head is occupied by a small circular or shield-shaped convex **facet** for articulation with the inner side of the lower extremity of the radius. It faces forward, downward, and inward.

The **anterior surface** of the head has the same general shape as the posterior. It is rough and convex from side to side and concave from above downward; it is marked by vascular foramina. The antero-external end is encroached upon by the radial facet and separated from the styloid process by a deep pit, in which is inserted the ulnar end of a strong ligament. Its posterior part is continuous below with the surface of the styloid process.

The **posterior border** of the head is rounded, and varies in breadth and degree of prominence.

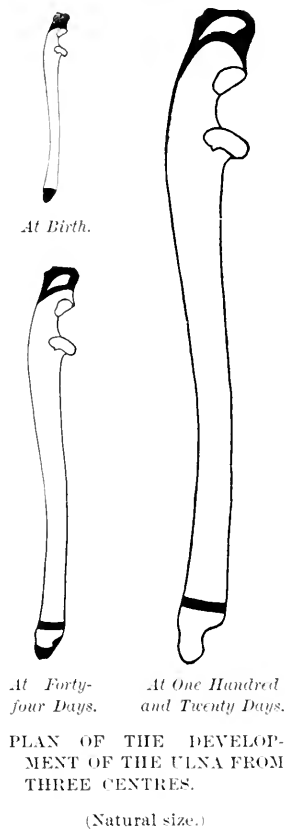
The **styloid**<sup>1</sup> process is the lower end of the bone produced backward and inward. It presents small, unimportant lateral surfaces and a rounded terminal surface. This is oval, the long diameter being directed nearly antero-posteriorly. The whole surface is smooth and convex. It articulates with two bones of the wrist as follows: by the anterior third of its inner side with the cuneiform, and by the posterior two-thirds of its inner side with the pisiform. Its outer part furnishes attachment for ligaments.

**Nomenclature.**—The word *ulna* is the name of a Latin measure of length equal to half a metre. It is derived from the Greek *olene*, meaning the arm. Celsus called the ulna the *cubitus*, the cubit, also a measure of length.

Both ulna and cubitus have been used for the elbow-joint. The German equivalent is *das Ellbogenbein*, the French is *le cubitus*.

<sup>1</sup> From *stilus*, a pen, and (Gr.) *eides*, like.

FIG. 443.



**Determination.**—When the ulna is held vertically, the olecranon above and the sigmoid cavity toward the student, the coronoid process is on the side to which the bone belongs.

**Articulation.**—The ulna articulates with the humerus, the radius, the pisiform, and the cuneiform.

**Muscular Attachments.**—The following muscles are attached to the ulna :

To the upper extremity, on the anterior surface, the **anconeus** and the inner humeral head of the **triceps**; on the external surface, the **anconeus**, the scapular and outer humeral heads of the **triceps**, the **extensor carpi ulnaris**, and the **extensor indicis**; on the posterior surface, the scapular head of the **triceps**; on the internal surface, the inner humeral and supracondyloid heads of the **triceps** and the ulnar heads of the **flexor carpi ulnaris** and **flexor profundus digitorum**; on the proximal surface, the posterior humeral and scapular heads of the **triceps**.

To the shaft, on the posterior surface, the **extensor indicis** and **extensor ossis metacarpi pollicis**; on the anterior surface, the radio-ulnar head of the **flexor profundus digitorum** and the **pronator quadratus**; on the internal surface, the **brachialis anticus** and the ulnar head of the **flexor profundus digitorum**.

**Blood Supply.**—The nutrient artery of the ulna is derived from the brachial artery, either directly or from its posterior interosseous branch.

**Ossification.**—The ulna arises from three principal centres of ossification,—one for the shaft, one for the posterior end of the olecranon, and one for the distal extremity.

#### VARIATIONS IN THE ULNA.

##### VARIATIONS IN SIZE.

The measurements of the ulna were taken as follows :

The maximum length is the distance from the olecranon to the tip of the styloid process.

The width at the upper extremity is the distance from the superior edge of the greater sigmoid cavity to the posterior surface.

The width at the lower end is the distance from the most projecting part of the superior edge of the facet for the ulna to the posterior border, in the same direction as the preceding measurement.

Side.	Maximum length.	Width at upper end.	Width at lower end.	Side.	Maximum length.	Width at upper end.	Width at lower end.
Left . . . .	93	8.5	5.5	Left . . . .	104	9.5	6
Right . . . .	93	9	5.5	Right . . . .	105	9	6
Left . . . .	95	9	6	Right . . . .	105	10	5.5
Right . . . .	95	9	6.5	Left . . . .	106	9	6
Left . . . .	97	8.5	5.5	Right . . . .	106	10.5	6
Right . . . .	97	9	6	Left . . . .	108	10	6.5
Right . . . .	97	9	6	Left . . . .	109	10	6
Left . . . .	97	10	6	Right . . . .	109	10	6
Right . . . .	97.5	9.5	6	Right . . . .	109	10.5	7
Right . . . .	98	8.5	5.5	Right . . . .	109	11	7
Left . . . .	98	9	6	Right . . . .	109.5	11.5	7.5
Left . . . .	98	9	6	Left . . . .	109.5	10.5	7
Right . . . .	98	9.5	6	Left . . . .	109.5	11	7
Right . . . .	98	9.5	6	Right . . . .	110	10.5	6.5
Left . . . .	98	10	6	Left . . . .	111	10.5	7
Right . . . .	98.5	10.5	6	Left . . . .	113	10	7
Right . . . .	99	9.5	6	Left . . . .	113	10	7
Right . . . .	99	9.5	6	Right . . . .	113	10	7
Right . . . .	99.5	9	6	Right . . . .	113	11	7
Left . . . .	100	9	6	Left . . . .	113.5	11	7
Left . . . .	100	9	6	Right . . . .	114	10	8
Right . . . .	100.5	9	6	Right . . . .	114	11	7
Right . . . .	100.5	9	6	Right . . . .	114	11.5	7.5
Right . . . .	100.5	10	7	Right . . . .	114.5	10.5	7
Left . . . .	101	9	6	Right . . . .	116.5	10.5	7
Left . . . .	101	10	6	Left . . . .	117.5	11	6.5
Right . . . .	101	10	6	Right . . . .	117.5	11	7
Right . . . .	101	10	6	Left . . . .	119	10	7
Left . . . .	101.5	10	6	Right . . . .	119.5	11.5	7
Right . . . .	101.5	11	6	Left . . . .	120	11	7
Right . . . .	102	9	6	Left . . . .	120.5	11	7
Left . . . .	102	9	6.5	Right . . . .	122	11	7
Left . . . .	103	9	6	Right . . . .	122	11	7.5
Right . . . .	103	9.5	6	Right . . . .	123	11	6.5
Right . . . .	103	9.5	6.5				

## VARIATIONS IN FORM AND DEVELOPMENT.

The ulna presents few striking variations. The greater sigmoid cavity either is a regular semicircle or, more commonly, the lower part is straighter and slopes slightly downward instead of curving upward. Rarely the lesser sigmoid cavity is flattened.

The external border of the shaft varies in prominence and the degree of roughness of its upper part.

The nutrient foramen sometimes is found in the external border. There may be a second foramen near by on the posterior surface.

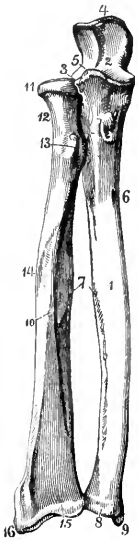
The lower extremity appears to vary only in the greater or less degree of backward projection of its head.

## HUMAN ULNA.

The ulna of man is relatively shorter and stouter than the ulna of the cat. The upper end is bent forward and inward.

The **greater sigmoid cavity** is at the upper limit of the proximal extremity, hence its upper edge is also the anterior superior edge of the olecranon. The sigmoid cavity is almost as broad as it is long, and it is more deeply concave. The olecranon part is separated from the lower part by a distinct ridge.

FIG. 444.



BONES OF THE RIGHT FORE-ARM. VIEWED IN FRONT; THE ULNA TO THE RIGHT AND THE RADIUS TO THE LEFT OF THE FIGURE.

1, shaft of the ulna; 2, greater sigmoid cavity; 3, articulation of the head of the radius with the ulna; 4, olecranon; 5, coronoid process; 6, nutrient foramen; 7, sharp ridges of both bones of the forearm for the attachment of the interosseous membrane; 8, head of the ulna; 9, styloid process; 10, shaft of the radius; 11, head of the same; 12, neck; 13, tuberosity; 14, roughened attachment of the pronator radii teres muscle; 15, distal extremity of the bone; 16, its styloid process.

its extent, and affords attachment to the flexor profundus digitorum muscle. To the lower and sharper part is fastened the pronator quadratus. In its upper third is the nutrient foramen of the bone.

The **external border** stretches from the back of the lower sigmoid cavity to the anterior side of the head. For most of its extent it is a sharp interosseous border for the attachment of the interosseous membrane. It separates the anterior and posterior surfaces.

The **coronoid process** has a thin edge facing upward, and is not a pyramidal process sloping downward, as in the cat. Its roughened anterior surface, sometimes called the **tuberosity** of the ulna, is an area of insertion of the brachialis anticus muscle; to a tubercle at its lower outer angle is fastened the oblique ligament; on its inner edge is a smooth tubercle for the attachment of the flexor sublimis digitorum muscle.

The **lesser sigmoid cavity** is not so deeply concave nor so regular as that cavity in the cat's ulna. The upper surface of the olecranon is not transversely concave; it forms an obtuse rounded angle with the posterior surface.

The **shaft** presents three borders, internal, external, and posterior, separating three surfaces, anterior, internal, and posterior.

The **internal border** begins above, at the inner side of the coronoid process, as a sharp ridge for the pronator radii teres and flexor longus pollicis muscles, and continues down to the styloid process. It is rounded for most of



The **posterior border** is subcutaneous; it begins on the olecranon and ends at the styloid process. Its upper part is prominent, but it becomes indistinct lower down. It separates the posterior and internal surfaces.

The **anterior surface** is marked above by two triangles, whereof the inner is the roughened so-called ulnar tuberosity and the outer is under the lesser sigmoid cavity and affords attachment to the supinator brevis muscle. The rest of the surface is a transversely concave area of origin for the flexor profundus digitorum muscle, except below, where it is rounded and offers attachment to the pronator quadratus.

The **posterior surface** is crossed by an oblique ridge, above which is a depressed area for the insertion of the anconeus muscle. Below the ridge the surface is divided into two parts by a longitudinal line: the narrow area near the posterior border is for the extensor carpi ulnaris; the broader area near the external border gives origin to the extensores ossis metacarpi pollicis, secundi internodii pollicis, and indicis.

The **internal surface** is marked above by a deep depression behind the coronoid process; below this depression it is flattened and at the lower end becomes rounded. Its upper three-fourths afford attachment to the flexor profundus digitorum; its lower fourth is subcutaneous.

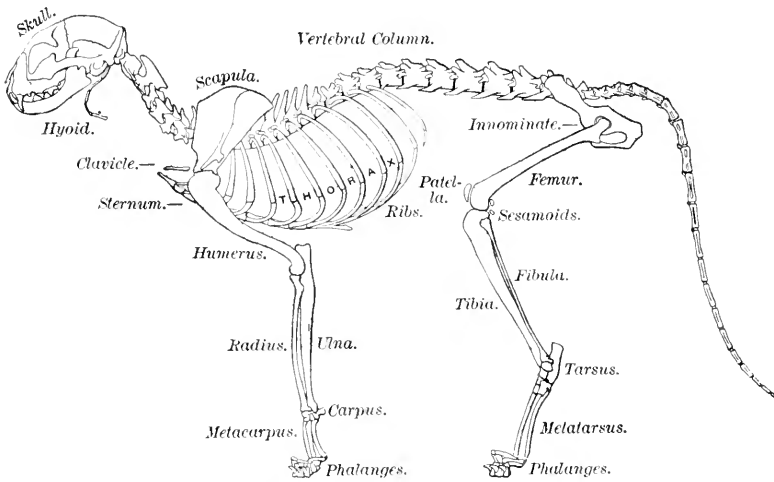
The **lower extremity** of the ulna is a rounded head, from the posterior side of which springs the small curved, obtusely pointed styloid process. Between the styloid process and the head, on the posterior aspect, is a groove for the flexor carpi ulnaris muscle. The transversely convex articular surface for the radius is more extensive than on the ulna of the cat, owing to the greater degree of rotation accorded the radius. The lower surface of the head is flattened for articulation with an interarticular cartilage which separates the ulna from the bones of the wrist.

### THE RADIUS.

**General Description.**—The radius is the shorter of the two bones of the forearm. It lies on the outer and anterior sides of the limb, but its position varies with the different movements of the hand. Its upper proximal end always maintains the same relation with the upper end of the ulna, lying to its outer side, but the lower end lies in front

of the lower end of the ulna to a greater or less degree according as the hand is held with the palm downward and backward or is turned inward. As a cat is unable to turn the palm of the hand directly forward without rotating also the humerus, the lower end of the radius can never lie wholly on the outer side of the lower end of the ulna. The shaft of the radius is parallel with the shaft of the ulna, or may cross it obliquely from above, downward, and inward, the ordinary position in walking. The radius articulates by its proximal end with the distal end of the humerus and with the contiguous side of the ulna, and by its distal or lower end not only with the scapho-lunar, the

FIG. 445.

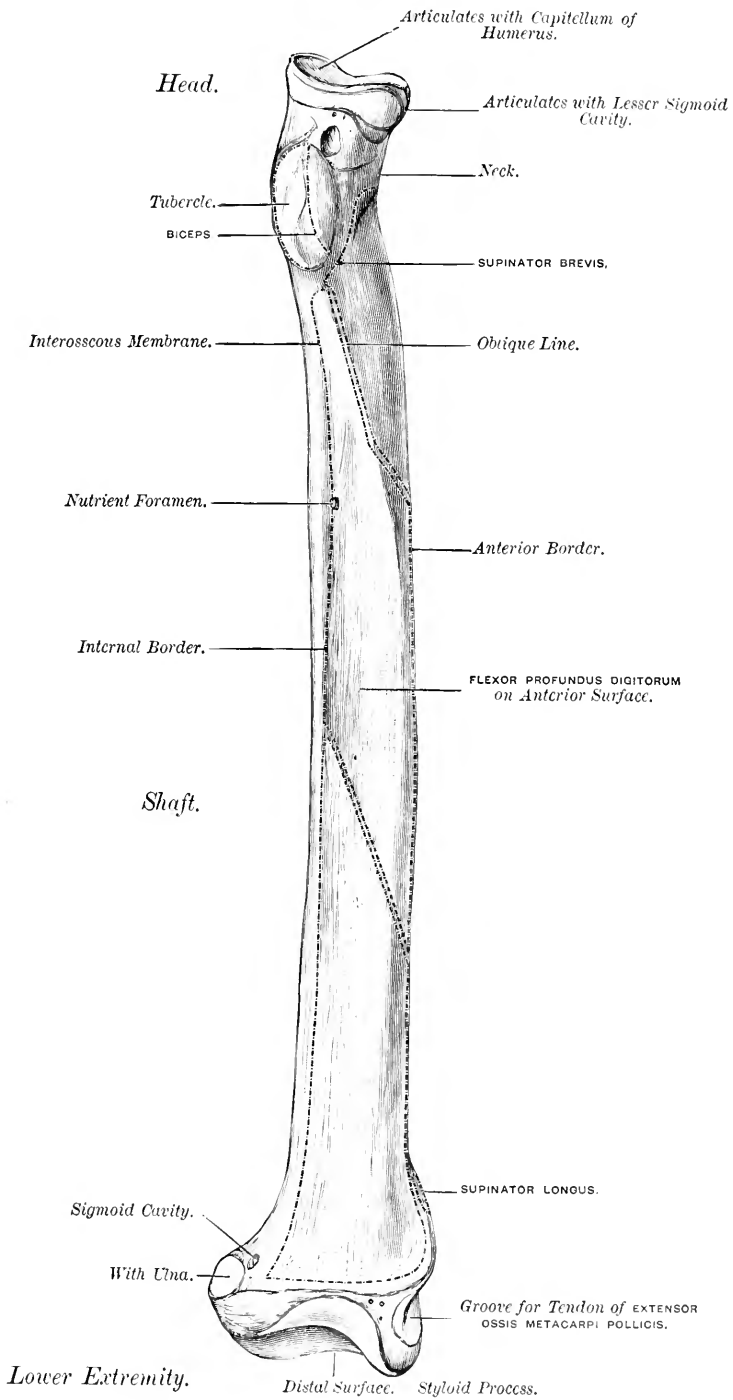


THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

principal bone in the proximal row of the carpus, or wrist, but also with the lower end of the ulna. Its shaft is bound to the shaft of the ulna by a strong interosseous ligament. The radius can be felt through the muscles of the forearm, and its outer edge is almost subcutaneous. The proximal end of the radius is smaller than the distal end. The shaft is arched from above downward, and the convexity of the arch is on the back of the forearm, which in walking faces forward. It is also slightly arched away from the ulna. For convenience of description, the bone may be held with the concave surface in front. The radius has three well-marked parts,—the upper extremity, the shaft, and the lower extremity.

The **Upper Extremity** comprises about one-ninth of the length of the entire bone. It is subcylindrical in shape and bent outward and

FIG. 446.



LEFT RADIUS, ANTERIOR SURFACE.

backward away from the long axis of the shaft. It appears also as if rotated about its long axis in such manner that its longest diameter is not transverse, as is the corresponding diameter of the shaft, but passes obliquely from the inner side in front backward and outward. The upper extremity consists of a head, a neck, and a tubercle.

The **head** is a small, terminal, oval disk which furnishes surfaces for articulation with the humerus and the ulna. It presents an oval proximal surface and a narrow marginal surface at right angles to it, which for most of the circumference is sharply divided from the neck below. The transverse diameter of the head is about one-fourth greater than the antero-posterior diameter. It does not lie exactly transversely, but is directed from without backward as well as inward. The degree of this obliquity varies in different bones.

The oval proximal surface (Fig. 447) forms a shallow cup which faces upward and also outward, is lined with cartilage, and articulates

FIG. 447.

*Back.**Inside.**Outside.**Front.*

HEAD OF RADIUS, PROXIMAL SURFACE.

with the capitellum of the humerus. It is limited by well-defined margins. Of these the front margin is sharp and forms also the front margin of the head. The margins at the sides and back are at some little distance from the edge of the head, a rounded border intervening and passing into the corresponding sides of the head. This rounded border is interrupted behind, at about the middle, by a notch, the continuation of a shallow vertical groove, on the dorsal surface.

The front of the marginal surface, the **anterior surface** of the head (Fig. 446), is narrow, strap-like, convex from side to side, and directed backward and downward from the sharp margin above. It is a smooth articular surface rotating in the lesser sigmoid cavity of the ulna. At the outer side this articular surface turns downward and ends obliquely, the rounded margin of the proximal surface cutting it off by turning downward. At the inner side it passes on the posterior surface.

The **posterior surface** (Fig. 448) is divided into two parts by a groove, which is not quite vertical, but runs outward as well as downward. The parts on each side of the groove are convex from side to side, and also from above downward, and pass into the neck below. They are covered by ligaments.

The **neck** is most clearly marked on the front and on the sides. It presents well-marked inner and outer borders dividing the anterior surface from the posterior surface. The anterior surface is concave in both directions, exhibiting a pit more or less distinct between the head and the tubercle. The inner part of the posterior surface faces backward, and the outer part backward and outward. The inner side of the anterior surface is continued on the tubercle, the other parts pass without a break into the shaft. The neck is pierced, especially on its anterior surface, by a number of foramina for blood-vessels, and is encircled by the orbicular ligament uniting the head with the ulna.

The **tubercle** is a linear oval swelling near the inner anterior border, between the neck above and the shaft below. The tendon of the biceps muscle is attached along its inner third, which is sometimes marked by a roughened depression.

The **Shaft** is narrow and nearly cylindrical above, but wide and flattened from before backward below. It presents on examination three borders, the anterior, the posterior, and the internal, and three surfaces, the anterior, the posterior, and the external. Of the three borders, the anterior and internal are well defined; the posterior is but faintly marked. The anterior and posterior surfaces are easily recognized; the external, however, is less evident.

The **anterior border** (Fig. 446), which may be also called the external, begins on the outer side of the neck and passes straight down to the front of the outer side of the lower end of the bone. At the junction of its upper and middle thirds it is joined by a second branch, known as the **oblique line** of the radius, which begins at the outer part of the lower end of the tubercle and runs obliquely downward and outward across the front aspect of the shaft. Just below the point where the oblique line ends the border is marked by a rough line from five to ten millimetres long, on which is inserted the pronator teres muscle. On the very end of the border, where it passes into the border of the lower extremity, is the small area of insertion of the supinator longus muscle. The oblique line separates the origin of

insertion of the supinator brevis muscle above from the area of origin of the radio-ulnar head of the flexor profundus digitorum below. The rest of the anterior border marks the external limit of the same flexor muscle and of the pronator quadratus, and separates them from the extensor ossis metacarpi pollicis arising on the external and posterior surfaces.

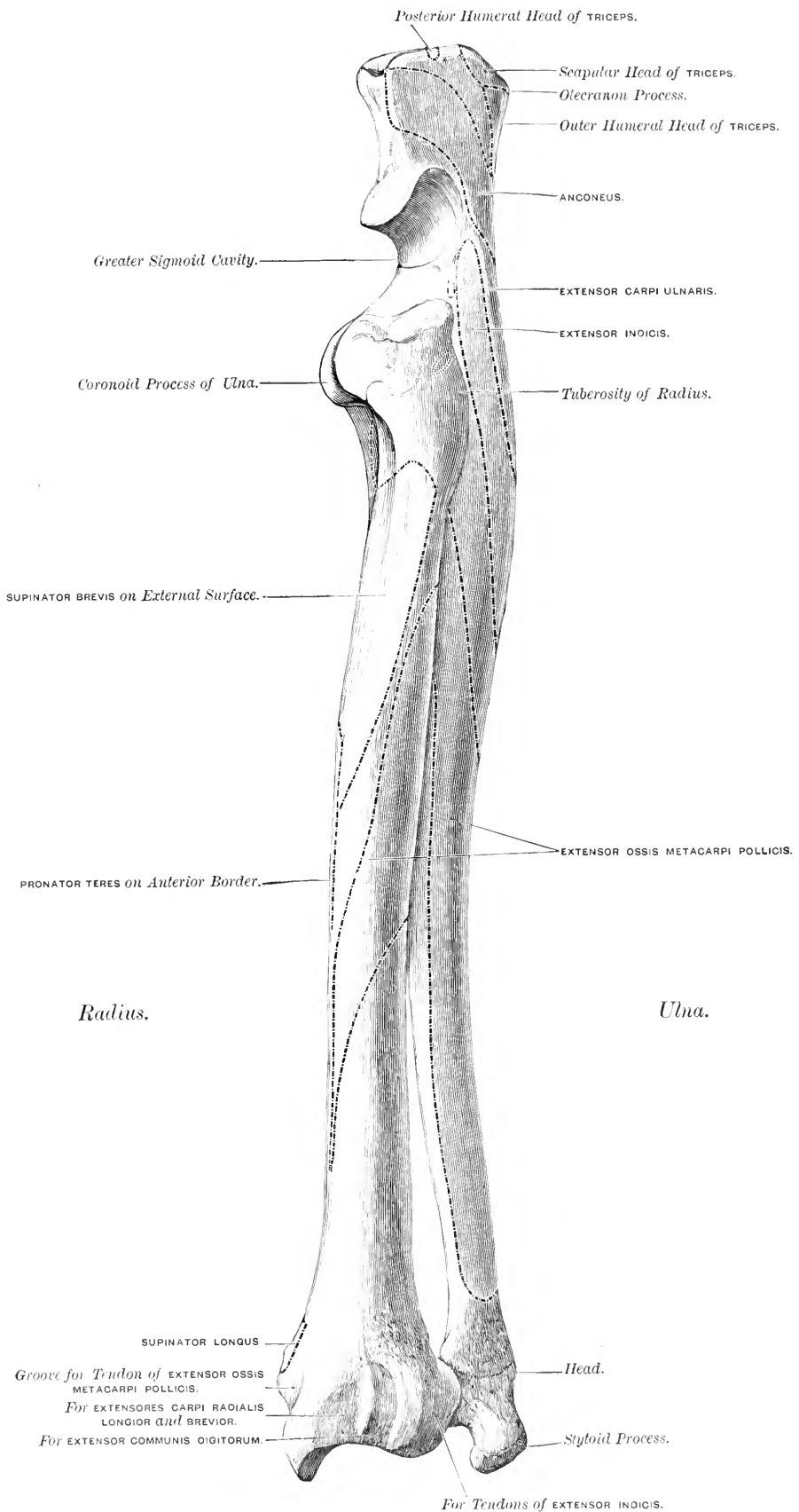
The **internal or interosseous border** (Fig. 446) begins above at the inner side of the tuberosity, near the origin of the oblique line, and extends inward and downward to the lower fourth, where it divides into two branches, which go to the anterior and posterior angles of the inner side, limiting a small triangular internal surface on the lower extremity. The internal border is rough at its upper part. It affords attachment to the interosseous ligament, which comes from the external border of the ulna. It separates the area of origin of the radio-ulnar head of the flexor profundus digitorum from that of the extensor ossis metacarpi pollicis muscles. It also limits the inner boundary of the origin of the pronator quadratus muscle.

The **posterior border** (Fig. 448) is not well marked, except in the middle of its course. It begins above on the inner side of the back of the neck, near the tubercle, and runs at first downward and obliquely outward, then, at about the middle of the bone, when it has passed the median line, it is continued straight down not far from the anterior border to the middle vertical ridge on the back of the lower extremity. The posterior border separates the area of origin of the supinator brevis from that of the extensor ossis metacarpi pollicis.

The **anterior surface** (Fig. 446) is distinct. It is divided by the oblique line into two parts. The upper part is small, wide above and pointed below; it is flattened or slightly convex transversely and faces forward and outward, affording an area of origin to the supinator brevis muscle. The lower larger part is limited by the anterior and internal borders. It is concave from above downward, and, in the upper half, concave also from side to side; in its lower half it is slightly convex transversely. The radio-ulnar head of the flexor profundus digitorum arises from the upper half, the pronator quadratus from the lower half. On the anterior surface, at the junction of the middle and upper thirds, near the internal border, is found the nutrient vascular foramen. It is directed toward the proximal end of the bone.

The **external surface** (Fig. 448) is bounded by the anterior and

FIG. 448.



RADIUS AND ULNA IN PRONATION, OUTER ASPECT.

posterior borders, and is wide above and long and narrow below. Its upper part is nearly flat, and faces inward and backward; it is a surface of origin of the supinator brevis. The lower part is convex from above downward and from side to side, and gives origin to a part of the extensor ossis metacarpi pollicis.

The **posterior surface** (Fig. 448) lies between the internal and posterior borders. It is narrow above, where these borders lie close together on the inner side of the posterior aspect, but much wider below, where the borders are further apart and parallel. It is convex from above downward and also from side to side, especially in the middle region. It faces backward and inward, giving attachment at its upper part to the extensor ossis metacarpi pollicis.

The **Lower Extremity** is moderately well defined from the shaft by its increased width and thickness. It presents a distal smooth articular surface, and anterior, posterior, and internal surfaces, separated by external and anterior and posterior inner borders. Its outer angle is prolonged into the styloid process.

The **external border** (Fig. 449) is the continuation of the external border of the shaft. It varies in different bones, but in most specimens is thin and sharp; it springs suddenly from the lower border of the shaft and runs forward as well as downward. The edge faces forward and outward, and is not continued on the styloid process, but stops abruptly at its base. It forms the outer part of the groove for the tendon of the extensor ossis metacarpi pollicis.

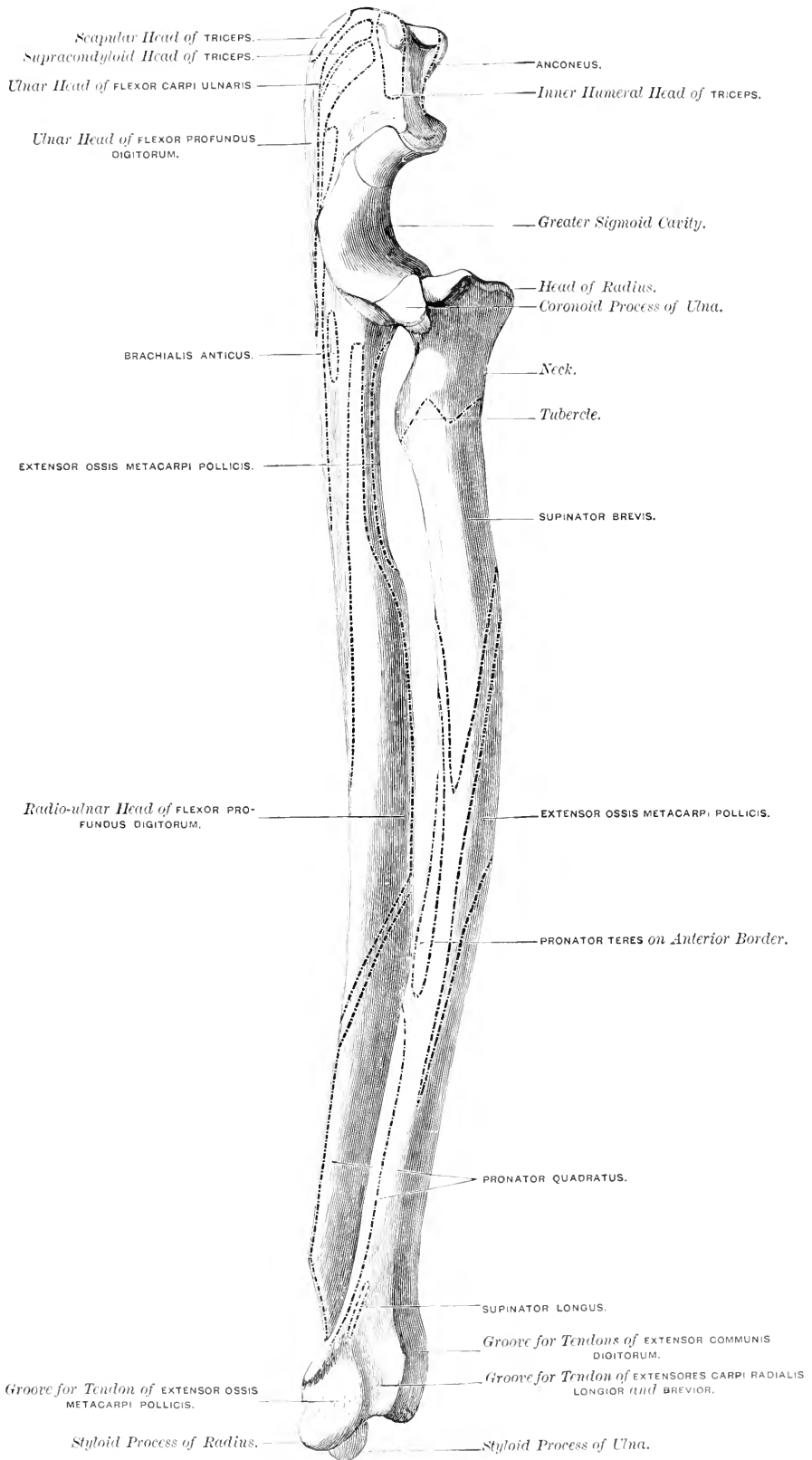
As has already been explained, the internal or interosseous border of the shaft divides at the lower end into two nearly parallel branches, which become the **anterior** and **posterior inner borders** of the extremity and enclose between them the internal surface.

The **internal surface** is slightly longer than wide; it is concave from side to side, and appears strongly concave from above downward, owing to the sudden sloping of the lower part inward and downward. At the lower edge, near the anterior border, is a small facet for articulation with the head of the ulna. This facet is transversely oval, slightly concave, and faces forward, upward, and inward.

The **anterior surface** (Fig. 446) is a prominent but narrow, transverse ridge stretching from the base of the styloid process to the ulnar articular facet on the internal surface. The ridge slopes upward and backward into the lower end of the shaft. In the angle between the



FIG. 449.



LEFT RADIUS AND ULNA, INNER ASPECT.

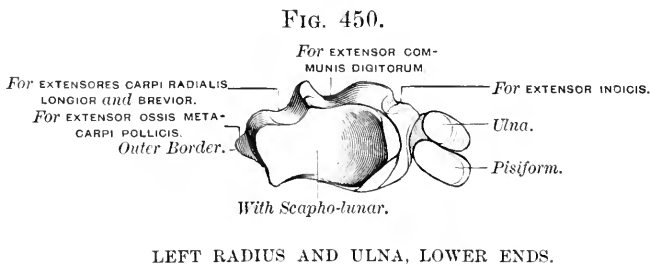
ridge and the outer border is a deep pit. The lower margin of the ridge is the anterior border of the distal surface of the radius.

The **posterior surface** (Fig. 448) is wider and longer than the anterior. It is convex from side to side, and divided by more or less prominent longitudinal ridges into four grooves. These grooves are converted by ligaments into canals, through which pass the tendons of the extensor muscles. The external groove lies between the base of the styloid process and the external border and lodges the tendon of the extensor ossis metacarpi pollicis. It is the smallest of the four, and runs obliquely forward and downward. The next groove lies between the beginning of the styloid process and a prominent ridge, which appears to be a continuation downward of the posterior border of the shaft. This ridge is the narrowest and highest of all, and lies to the outer side of the longitudinal axis of the bone. The groove is well marked, concave from side to side, and convex from above downward, and holds the tendons of the extensores carpi radialis longior and brevior. The third groove is as wide as the preceding and a little longer. It, also, is concave from side to side, but is almost flat from above downward. It lodges the tendons of the extensor communis digitorum. The ridge which forms the inner boundary of this groove is low and nearly as broad as the groove itself. To the inner side of this ridge is the fourth groove, which, although smaller than the two immediately preceding, is well marked. It runs more obliquely downward and inward, and lodges the tendons of the extensor indicis. The tendons of the extensor minimi digiti lie over the line of articulation of the radius with the ulna.

The **distal surface** of the lower extremity (Fig. 450), and therefore of the whole bone, is transversely oval, and about twice as wide as deep. It is shorter from before backward at the outer side than at the inner side, and its outer border is prolonged downward and slightly outward into the styloid process. The **posterior border** is rounded and prominent except just within the styloid process, where it is continuous with the groove for the radial extensors of the wrist. Beyond this point, the prominent border is twice emarginated for the outer two grooves on the posterior surface. The **anterior border** is sharp and prominent except near the styloid process, where it becomes emarginate, smooth, and continuous with the anterior wedge-like surface. The **inner border** is a narrow curved strip which slopes upward and inward from the

arcuate outer edge of the distal articular surface. From side to side the distal surface is strongly concave, the outer part facing in great measure inward. From before backward its inner half is concave, while the outer half is distinctly convex. It articulates with the proximal surface of the scapho-lunar bone.

The **styloid process** is a blunt conical tubercle extending several millimetres below the distal articular surface. Its outer posterior surface is rough, and its base forms the partition between the grooves for the extensor ossis metacarpi pollicis and extensor carpi radialis. Its outer anterior surface, which is triangular and rough, begins at the abrupt termination of the outer border of the extremity. Its inner lower surface is smooth, and forms the saddle-shaped outer part of the distal surface which fits in the shallow concavo-convex surface on the upper surface of the scapho-lunar.



**Nomenclature.**—The word radius was introduced into osteology by Celsus. It was applied to any rod-like object. Galen called the radius *kerkis*, a word used by Homer to denote a weaver's shuttle. The colloquial German word is *die Speiche*; the French use *le radius*.

**Determination.**—If the radius be held with the anterior concave surface uppermost and the head toward the student, the styloid process will be on the side to which the bone belongs.

**Articulation.**—The radius articulates with the humerus, the ulna, the scapho-lunar, and slightly with the pisiform.

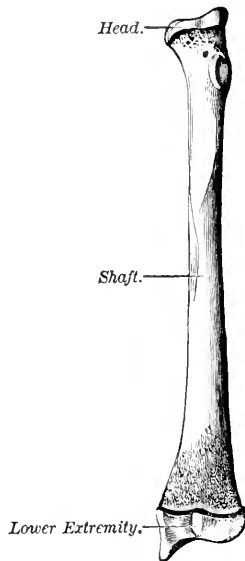
**Muscular Attachments.**—To the anterior surface are attached the insertion of the **supinator brevis**, and the fibres of origin of the radio-ulnar head of the **flexor profundus digitorum** and the **pronator quadratus**; to the anterior border, the insertion of the **supinator brevis**, the **pronator teres**, and the **supinator longus**; to the external and posterior surfaces, the **supinator brevis** and fibres of origin of the **extensor ossis metacarpi pollicis**; to the internal border,

the interosseous membrane which divides the flexor muscles from the extensors and gives origin to fibres of each. To the tubercle is fastened the tendon of the **biceps**, the principal flexor of the forearm upon the arm.

**Blood Supply.**—The radius is supplied with blood from the brachial artery through a small nutrient branch, arising from the anterior interosseous, sometimes in common with the nutrient artery of the ulna.

**Ossification.**—The radius develops from three principal centres (Fig. 451), one for each extremity and one for the shaft, to which a small centre for the tubercle is said to be added after birth.

FIG. 451.



PLAN OF THE DEVELOPMENT OF THE RADIUS BY THREE CENTRES.

#### VARIATIONS IN THE RADIUS.

##### VARIATIONS IN SIZE.

The measurements of the radius were taken as follows :

The maximum length is the distance from the top of the head to the tip of the styloid process.

The diameter at the head is the greatest diameter of the proximal surface.

The width at the lower end is the greatest transverse diameter.

Side.	Maximum length.	Diameter at head.	Width at lower end.	Side.	Maximum length.	Diameter at head.	Width at lower end.
Right . . . .	79	7	11.5	Left . . . .	88	8	12.5
Left . . . .	79	7	11.5	Right . . . .	88	8	13
Right . . . .	80	7.5	11	Right . . . .	88	9	13
Left . . . .	80	7.5	11	Right . . . .	88.5	8	11
Left . . . .	81	7.5	10.5	Left . . . .	88.5	8	12.5
Left . . . .	81	7.5	11.5	Right . . . .	89	8.5	12
Right . . . .	81	8	11.5	Left . . . .	89	9	13
Right . . . .	81.5	7.5	11.5	Right . . . .	90	8	12
Right . . . .	81.5	8	12	Right . . . .	90	8	12.5
Left . . . .	82	7	11	Left . . . .	90	8	12.5
Left . . . .	82	7.5	11	Left . . . .	91	8	12.5
Left . . . .	82	8	11.5	Left . . . .	91	8.5	13
Right . . . .	82	8	12.5	Left . . . .	91	8.5	13
Left . . . .	82	8	13	Right . . . .	91	8.5	13
Right . . . .	83	7	11	Right . . . .	92	9	12
Right . . . .	83	8	12	Right . . . .	92	9	13
Right . . . .	83	8	12	Left . . . .	92	9	13
Right . . . .	83	8.5	12	Right . . . .	92	9	14
Right . . . .	83.5	8	12	Left . . . .	92.5	8	12.5
Right . . . .	84	8	11.5	Left . . . .	93	9	13
Right . . . .	84	8.5	12.5	Right . . . .	96	8	13
Right . . . .	84.5	7	11.5	Left . . . .	96	8.5	13
Left . . . .	84.5	8	11.5	Right . . . .	96	9	12
Left . . . .	84.5	8	12	Left . . . .	96	9	13
Left . . . .	85	7	11.5	Left . . . .	96.5	9	14
Left . . . .	85	8	12	Left . . . .	98.5	9	12.5
Right . . . .	86	8	12	Right . . . .	99	9	13
Left . . . .	86	8	12.5	Right . . . .	101	9	13.5
Right . . . .	86	8.5	12.5	Left . . . .	101	9	13.5
Right . . . .	87	7.5	11	Right . . . .	102.5	10	13.5
Right . . . .	87	8	12.5	Right . . . .	104	9	13.5
Right . . . .	87	8	12.5	Right . . . .	105	9	14
Left . . . .	87	8	12.5	Right . . . .	105	9	14
Left . . . .	87	8	12.5				

## VARIATIONS IN FORM AND DEVELOPMENT.

I have seen very few variations in the radius. In some skeletons the bone is almost straight, in others it is so strongly bowed that the anterior surface and the internal border are concave from above downward.

The **notch** on the posterior border of the head is often limited externally by a distinct tubercle.

The **nutrient foramen** is very constantly on the anterior surface near the internal border, and in the lower part of the upper third of the bone; rarely it is further removed from the border, or even near the oblique line.

The **anterior surface** in some specimens is marked by an oblique

line at the upper limit of the area of attachment of the pronator quadratus muscle.

The posterior border may be absent, in which case it is represented by the maximum convexity of the posterior aspect of the bone.

### HUMAN RADIUS.

The radius of man differs from the radius of the cat (Fig. 453) in a few details only. The proximal surface of the head is almost circular; the marginal surface presents a more extensive articular band, because the radius can rotate more completely around its long axis, bringing the lower end parallel with the ulna and placing the hand in absolute supination, which the radius of the cat cannot do. The head and neck are not bent so strongly outward from the axis of the shaft.

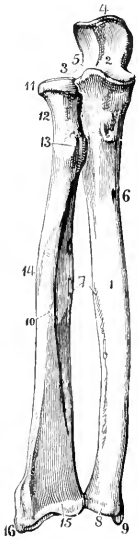
The tubercle is marked more deeply by the insertion of the biceps muscle.

The shaft presents the same anterior, internal, and posterior borders, likewise separating anterior, posterior, and external surfaces. Some authors give only two borders, the inner and the outer, and two surfaces, the anterior and posterior; in this case the outer border is equivalent to the anterior border and external surface, and the posterior border is not distinguished from the general posterior surface.

The internal or interosseous border is distinct, and separates the anterior and posterior surfaces. The upper part of the anterior border is formed by the oblique line, and therefore begins at the tubercle, and not at the outer side of the head. The area above the line for

the supinator brevis muscle, which in the cat I have called part of the anterior surface, is in man rounded and faces outward as part of the external surface. The area of attachment of the pronator quadratus on the lower part of the anterior surface is less extensive in man than

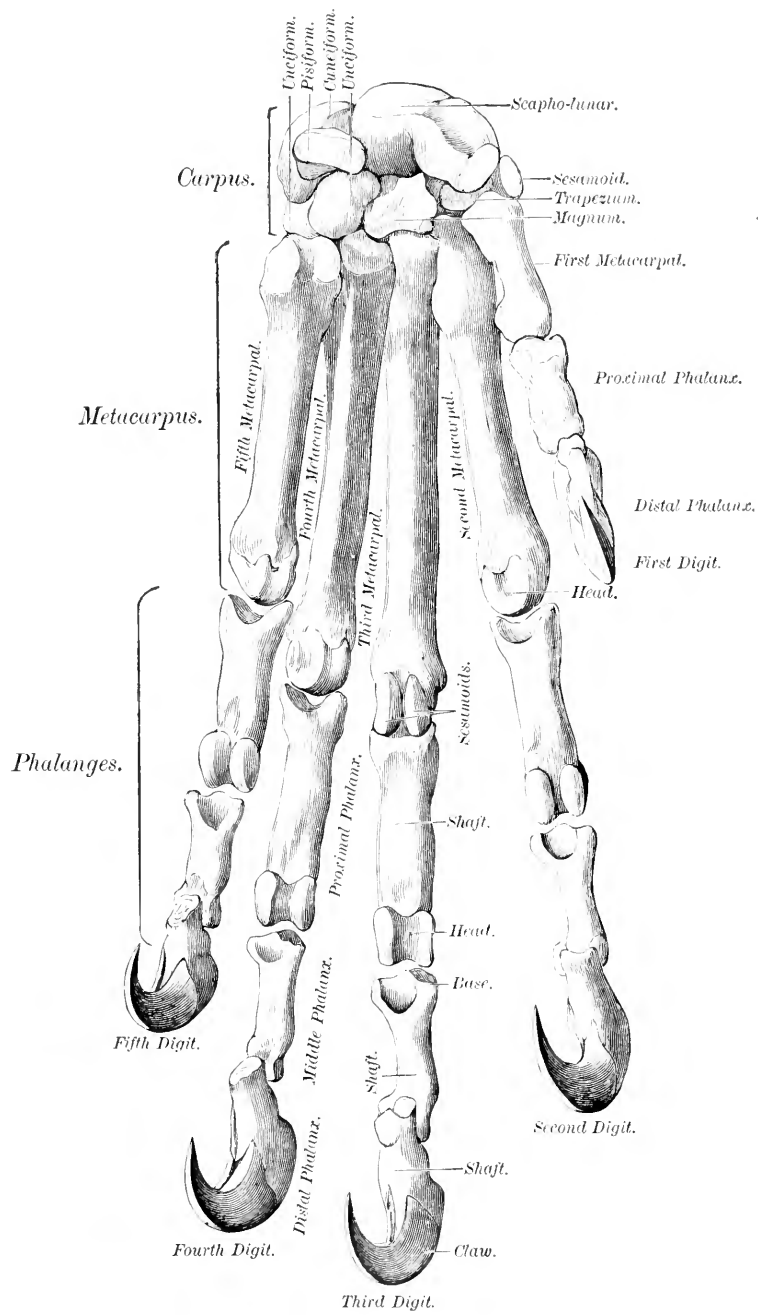
FIG. 452.



BONES OF THE RIGHT FORE-ARM. VIEWED IN FRONT; THE ULNA TO THE RIGHT AND THE RADIUS TO THE LEFT OF THE FIGURE.

1, shaft of the ulna; 2, greater sigmoid cavity; 3, articulation of the head of the radius with the ulna; 4, olecranon; 5, coronoid process; 6, nutrient foramen; 7, sharp ridges of both bones of the forearm for the attachment of the interosseous membrane; 8, head of the ulna; 9, styloid process; 10, shaft of the radius; 11, head of the same; 12, neck; 13, tuberosity; 14, roughened attachment of the pronator radii teres muscle; 15, distal extremity of the bone; 16, its styloid process.

FIG. 453.



LEFT HAND, PALMAR ASPECT.

in the cat. The **posterior border** is rather the maximum convexity on the posterior aspect of the bone. The **external surface** is rounded and marked half-way down by the roughened area for the pronator radii teres muscle. The **posterior surface** is rounded above and below, but flattened in the middle, where the extensor primi internodii pollicis muscle is attached.

The grooves on the posterior aspect of the lower extremity are slightly different from those presented by the radius of the cat. The larger inner one, which in the cat is for the extensor indicis, is for the tendons of the extensores indicis, communis digitorum, and minimi digiti; the next one, which in the cat transmits the extensor communis digitorum, transmits the extensor secundi internodii pollicis; the area external to the median ridge is subdivided into two grooves for the extensores carpi radialis breviar and longior; and instead of a single groove on the outer aspect for the extensor ossis metacarpi pollicis, there are two, the inner for that muscle, the outer for the extensor primi internodii pollicis.

### THE CARPUS.

**General Description.**—The Carpus, or wrist, is the proximal and smallest part of the hand. It is composed of seven small bones, united closely to form a compact mass about twice as wide as it is long and twice as wide as it is thick from the dorsal to the palmar side. The carpus constitutes a very small portion of the upper extremity, as its length is contained twelve or thirteen times in the length of the ulna alone and forms only an eighth or ninth of the total length of the hand. The carpus presents four well-defined surfaces.

The larger quadrilateral **dorsal surface** is bounded by approximately straight radial and ulnar borders, and by proximal and distal borders rendered irregular by the slightly differing sizes of the constituent bones. The surface is convex from side to side, the maximum convexity being nearer the radial border than the middle line.

The smaller **palmar surface** is concave from side to side, and is very irregular, inasmuch as it affords attachment to strong ligaments. At its ulnar proximal end it is prolonged into a stout palmar hook.

The transversely oblong **proximal surface** is convex in both directions for articulation with the biconcave articular surface formed by the ends of the radius and ulna.



The **distal surface** is transversely elongated, and in the main concave from the dorsal to the palmar side, and convex from side to side. The radial half is depressed below the ulnar half. The distal surface is smooth, for articulation with the five metacarpal bones. The dorsal and palmar surfaces meet at the obscurely defined radial and ulnar borders.

The seven carpal bones are arranged in two transverse rows, with three in the proximal row and four in the distal row. Counting from the radial side, the proximal row is composed of the **scapho-lunar**, the **cuneiform**, and the **pisiform**, and the distal row is composed of the **trapezium**, the **trapezoid**, the **os magnum**, and the **unciform**.

These carpal bones are modified from a cubical type, and hence present six surfaces, proximal, distal, dorsal, palmar, radial, and ulnar.

Of these surfaces the **dorsal** and **palmar** are free from articular facets, as they do not join other bones, but form the back and front of the wrist.

The **proximal** and **distal surfaces** articulate with the lower ends of the bones of the forearm or the upper ends of the metacarpal bones, or form the articulation between the two rows.

The **radial** and **ulnar surfaces** are articular surfaces on some of the carpal bones; on others, depending on the position of the individual bone, they assist in producing the radial and ulnar edges of the wrist.

The dorsal surface of the carpus is convex because the dorsal surfaces of the constituent bones are larger than their palmar surfaces, and because the bones themselves are arranged as the arc of a circle whose centre would lie without the general palmar surface of the carpus. It will also be noticed that the proximal ends of the carpal bones are larger than their distal ends, and that the bones appear to radiate from a centre in the proximal border of the wrist. The small hemispherical ossicle on the radial side of the proximal row is not considered an element of the wrist, but is classed among the sesamoid bones.

**Ossification.**—Each carpal bone develops from a single centre, except the scapho-lunar, which is a composite of three bones, two of which, the scaphoid and the lunar, are found as distinct bones in man, and the third, the *os centrale*, is present as a separate element in a number of other mammals.

To the seven carpal bones and the radial sesamoid, which normally constitute the wrist, at least one more separate ossicle is sometimes added as an anomaly. This bone has been seen in certain specimens lying between the scapho-lunar and the magnum, and has been recognized as the *os centrale 2* which obtains normally in some other animals.

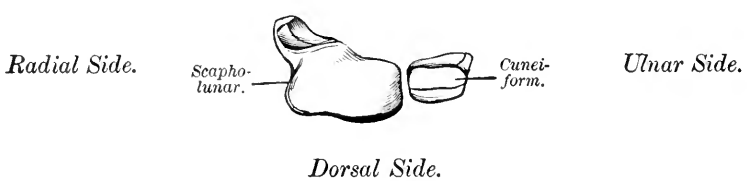
**Nomenclature.**—Three sets of names are employed for the carpal bones. The first is that given above, and used generally by English and American anatomists, the second is used by European anatomists, and the third by comparative anatomists. They may be shown as follows :

1	2	3
Scaphoid.	Os scaphoideum.	Os radiale.
Semilunar.	Os lunare.	{ Os intermedium. Os centrale 1. Os centrale 2.
Cuneiform.	Os cuneiforme.	Os ulnare.
Pisiform.	Os pisiforme.	
Trapezium.	Os multangulum majus.	Os carpale I.
Trapezoid.	Os multangulum minor.	Os carpale II.
Magnum.	Os capitatum.	Os carpale III.
Unciform.	Os hamatum.	Os carpale IV. + V.

Carpus comes from the Greek *carpos*, which was introduced into osteology by Galen. *Carpos* may be derived from *carpho*, to shrink together (hence applicable to the narrowest part of the arm), or from *harpo*, to grasp. Galen did not give separate names to the carpal bones, but merely distinguished them by number. Lyser (A.D. 1665) gave them the names by which they are known in human anatomy.

PROXIMAL ROW OF CARPAL BONES.

FIG. 454.  
*Palmar Side.*



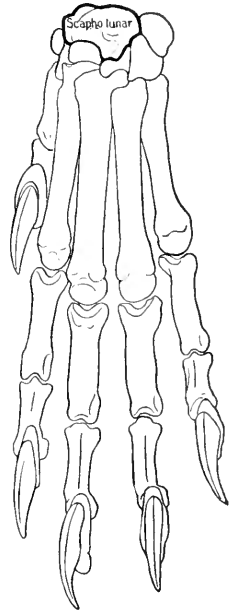
PROXIMAL ROW OF LEFT CARPAL BONES IN POSITION, PROXIMAL ASPECT.

## THE SCAPHO-LUNAR.

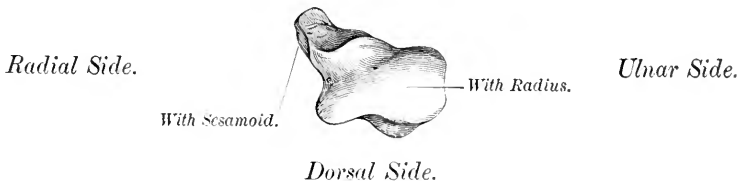
**General Description.**—The Scapho-lunar is the largest bone of the carpus, and forms the greater part of its proximal aspect. It lies on the radial side of the hand, and articulates with the lower end of the radius and with all the other carpal bones (Fig. 455). It is in the main rectangular in form, but appears irregular, owing largely to the prolongation of the radio-palmar corner into a distinct process. The length of this process is about equal to a third of the radio-ulnar width of the bone, and its direction is to the radial and palmar sides of the wrist. The scapho-lunar presents for examination six surfaces.

The **proximal surface** (Fig. 456) may be recognized as the largest, smoothest, and most convex. It consists of two parts, the surface of the bone proper and the surface of the process. The former, which is much larger, is almost rectangular, and nearly twice as wide as long. From side to side it is distinctly convex, and from before backward it is convex at the ulnar end and concave at the radial end. It is covered with cartilage, and articulates with the lower end of the radius. Its dorsal border is smooth and rounded and passes without a definite line into the dorsal surface. Its ulnar border is straight or slightly emarginate. The ulnar half of the palmar border

FIG. 455.



POSITION OF SCAPHO-LUNAR.

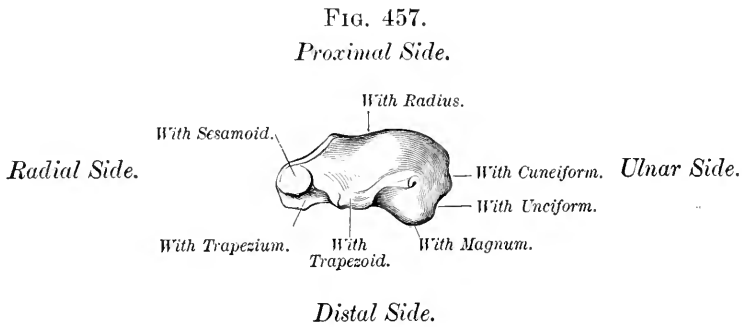
FIG. 456.  
*Palmar Side.*

LEFT SCAPHO-LUNAR, PROXIMAL SURFACE.

is rounded, and the radial half is elevated to a sharp crest, which is continued as the proximal surface of the process. The radial border is directed from the front obliquely backward and outward and is

emarginate, the emargination limiting the concavity for the styloid process of the radius.

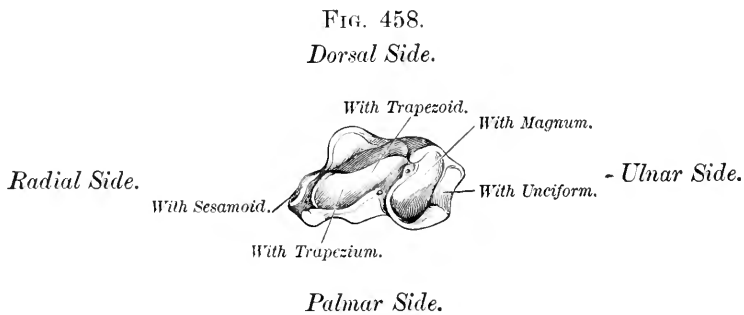
The dorsal surface (Fig. 457) is triangular; the base of the triangle is at the proximal side, and the apex points distally. The



LEFT SCAPHO-LUNAR, DORSAL SURFACE.

proximal border is rounded, allowing the surface to pass insensibly into the proximal surface above. The outer or radial border is emarginate, to receive the trapezoid. Its inner or ulnar border presents two emarginations, which are the edges of the articular cavities for the os magnum and the unciform, situated on the distal surface of the bone. The dorsal surface of the scapho-lunar is gently convex from side to side, and roughened for the attachment of ligaments.

The distal surface (Fig. 458) is irregular, and exhibits four secondary articular surfaces, which are covered with cartilage and articulate



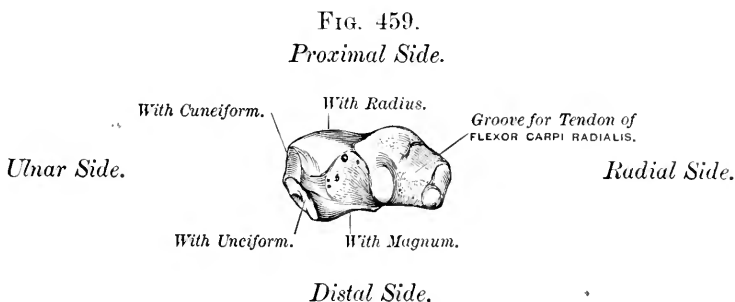
LEFT SCAPHO-LUNAR, DISTAL SURFACE.

with all the distal carpal bones. The smallest of these facets occupies the greater part of the under surface of the process of the bone. It is triangular, almost flat, and joins the proximal surface of the trapezium. Behind this area is a larger facet for the trapezoid; this is also

irregularly triangular, the widest part being at the dorsal border. It is divided into two parts by a groove passing obliquely from the ulnar side of the dorsal border to the radio-palmar angle. The radial part is slightly concave, and faces downward and to the ulnar side of the hand, while the ulnar part is strongly convex from side to side, and faces to the radial side. On the ulnar side of this facet is a ridge which passes obliquely to the radial and palmar sides, parallel to the groove just described, and divides the whole under surface into two parts. On the ulnar side of this ridge is the narrow, deeply concave surface for the vertical plate of the magnum. This groove is wider behind than in front, faces downward and inward, and is directed obliquely across the bone, but leaves a small pit near the palmar border, between it and the ridge on the radial side. The pit furnishes a point of insertion for a ligament. Next to this facet, and separated from it by a slightly elevated line, is the curved surface for the unciform. This is crescentic in outline, the emarginate side toward the radial side of the bone. It is concave in a dorso-palmar direction, faces distally and radially, and receives the narrow proximal end of the unciform.

The **ulnar surface** is flat and attached by ligament to the radial side of the cuneiform. Its arcuate upper margin passes into the rounded proximal surface of the bone, and its emarginate distal margin is sharply defined by the edge of the facet of the unciform.

The **palmar surface** (Fig. 459) is almost rectangular, and about twice as wide as high. Its ulno-distal angle is cut off squarely, and



LEFT SCAPHO-LUNAR, PALMAR SURFACE.

the radio-distal angle is produced into the process of the bone. The surface is nearly flat, and is rough for the attachment of ligaments. Its ulnar and distal borders are sharply defined, but the ulnar part of its



proximal border is continuous with the rounded proximal surface of the bone. The surface on the process exhibits a wide, shallow groove, which is covered with cartilage on each side and converted by strong ligaments into a canal for the tendon of the flexor carpi radialis muscle.

There is no radial surface to the bone proper, as the proximal and distal surfaces meet in a sharp line, but the process of the bone exhibits a rounded radial aspect which faces dorsally as well as radially, and bears a circular facet for the sesamoid bone in the tendon of the extensor ossis metacarpi pollicis muscle.

**Nomenclature.**—The scapho-lunar is composed of two bones, separated in man and many animals, named the scaphoid and the lunar, hence the name is a compound of the two words. In the human hand the scaphoid has the shape of a keeled boat (in Greek *scaphe*) and the lunar is crescentic. The scapho-lunar is also called the *radiale* and the *intermedium*.

**Determination.**—If the rounded proximal surface be held upward and the triangular dorsal surface toward the student, the process of the bone will point to the side to which the bone belongs.

**Articulation.**—The scapho-lunar articulates with the radius above, with the cuneiform on the inside, and with the unciform, the magnum, the trapezoid, and the trapezium below.

**Ossification.**—The scapho-lunar develops from at least two centres of ossification, and sometimes from three, the third representing the os centrale found normally in the carpus of some other mammals.

### THE CUNEIFORM.

**General Description.**—The Cuneiform is the small bone on the ulnar side of the proximal row (Fig. 461). It may be distinguished from the other small bones of the carpus by its stout oblong form and its very convex proximal surface.

The cuneiform has five surfaces. When the pisiform, which lies behind it, is in place, the proximal surface appears as a ridge which is about twice as long transversely as it is wide in a dorso-palmar direction; it faces to the ulnar side as well as upward, and is convex in both directions. It is covered with cartilage, and articulates with a facet on the anterior surface of the styloid process of the ulna.

The ulnar surface passes without abrupt lines into the dorsal surface in front and into the proximal surface above. On the palmar side

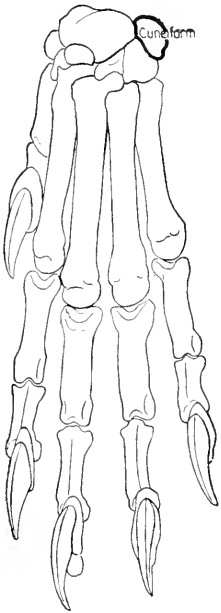
is the continuation from the proximal surface of the narrow facet for the ulna. The remaining triangular surface is rough for the attachment of ligaments.

The distal surface (Fig. 463) is slightly wider in the transverse than in the dorso-palmar direction. Its palmar, dorsal, and radial borders are straight; its ulnar border is arcuate and oblique. Almost the entire distal surface is occupied by a flat articular facet for the unciform. This facet has a distinct emargination on the palmar side for a rough pit in which is inserted the strong ligament which passes to the ulnar surface of the unciform. When the bone is in position the distal surface faces as much to the radial side as downward.

The radial surface scarcely exists as a distinct surface, since the proximal surface comes down on the radial side almost to the distal surface, leaving little more than a roughened border between the dorsal and palmar surfaces. This border is united with the ulnar border of the distal surface of the scapho-lunar by a wide ligament.

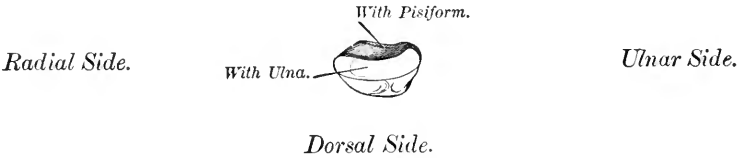
The dorsal surface (Fig. 460) is in the main rectangular. It is wider than high, and the ulno-distal angle is slightly produced. Its upper border is arcuate and passes without an angle into the ulnar border, which forms an acute angle with the almost straight distal border. The radial border is curved, and the radio-proximal angle in most cases

FIG. 461.



POSITION OF CUNEIFORM.

FIG. 462.  
*Palmar Side.*

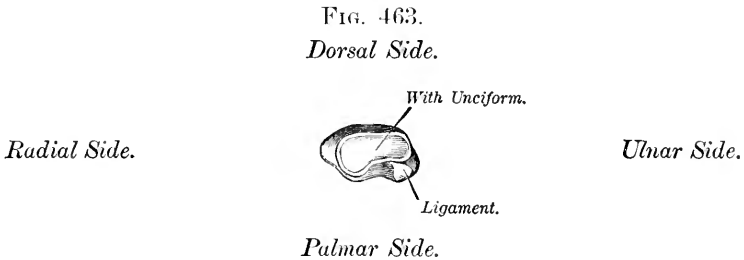


LEFT CUNEIFORM, PROXIMAL SURFACE.

is rounded off. The surface itself is gently convex, and rough for ligamentous attachment.



The **palmar surface** appears as a downward and backward continuation of the proximal surface. Its upper border is curved and rounded; it forms part of the proximal facet for the ulna. The radial border is nearly straight and parallel with the ulnar border; both borders pass obliquely distally and to the ulnar side. The distal



LEFT CUNEIFORM, DISTAL SURFACE.

border is straight. An articular facet occupies the entire surface, except near the proximal and ulnar borders. The facet is concave from the proximal to the distal margin, and articulates with the facet on the dorsal surface of the base of the pisiform.

**Nomenclature.**—The word cuneiform is composed of *cuneus*, a wedge, and *forma*, likeness. A similar idea is expressed in the widely used synonym *os triquetrum*, the triangular bone. These designations are translated into German by *das Pyramidenbein* and *das Dreieckigebein*. The French use *le pyramidale*. In comparative anatomy the cuneiform is known as the *ulnare*.

**Determination.**—If the proximal surface be held upward and the dorsal surface toward the student, the produced palmo-ulnar angle will point to the side to which the bone belongs.

**Articulation.**—The cuneiform articulates with the ulna, the unciform, the pisiform, and the scapho-lunar.

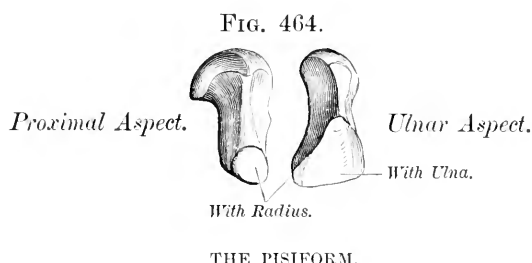
**Ossification.**—The cuneiform develops from one centre of ossification.

#### THE PISIFORM.

**General Description.**—With the exception of the scapho-lunar, the Pisiform is the largest bone in the carpus. It may be recognized by its oblong form and its swollen, hooked end. It is irregular in shape, and is nearly twice as long as wide. When in its place in the carpus, the long diameter is directed in a dorso-palmar direction. It may be described as composed of three parts, a base, a shaft, and a head.

The **base** is the end which bears the articular facets. It is oblong;

the long diameter is directed obliquely from the radial to the ulnar and proximal side. It is therefore compressed from side to side, so that its proximo-distal diameter is twice as great as its radio-ulnar diameter. Its dorsal surface is occupied by an articular facet which



is slightly crescentic in outline, with the arcuate border on the radial side. It is gently convex from side to side, and applied to the facet on the palmar surface of the cuneiform.

The proximal prominent end of the base bears a small convex surface which meets the side of the radius. On the ulnar side of the base, and extending for a distance on the ulnar border of the shaft, is a large triangular concave articular surface for the styloid process of the ulna. This faces upward as well as to the ulnar side.

The shaft and head are compressed from above downward, and the radio-ulnar diameter is greater than the proximo-distal. The ulnar border of the shaft is encroached upon below by the facet for the ulnar. The proximal, radial, and distal surfaces are convex from side to side and slightly concave from the dorsal to the palmar end.

The head is the terminal palmar enlargement of the shaft. The enlargement is extended in the form of a hook, upon which is inserted the tendon of the flexor carpi ulnaris muscle. It is divided from the shaft by a more or less marked curved line, so that when seen from behind its outline is oval, and when seen from the sides its shape is crescentic, the concavity facing dorsally.

**Nomenclature.**—Pisiform is compounded of *pisum*, a pea, and *forma*, likeness, from the shape of the human bone. *Os pisiforme*, *le pisiforme*, and *das Erbsenbein* have the same meaning. It is sometimes known as *os carpi accessorium* or *flexorium*.

**Determination.**—When the proximal side, known by the prominent end of the base, is upward, and the dorsal side, with the oval or crescentic facet on the base, is toward the student, the hook on the head points to the side to which the bone belongs.

**Articulation.**—The pisiform articulates with the radius above, the ulna on the inside, and the cuneiform in front.

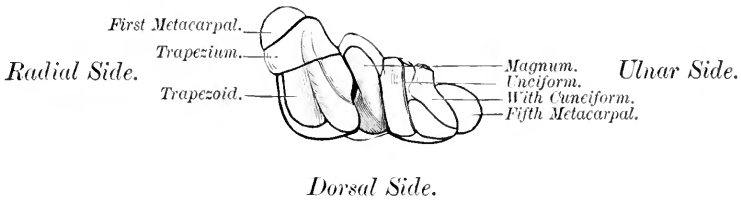
**Muscular Attachments.**—To the head of the pisiform is attached the flexor carpi ulnaris; the distal surface of its shaft affords origin to the abductor minimi digiti.

**Ossification.**—The pisiform develops from one centre of ossification.

#### DISTAL ROW OF CARPAL BONES.

FIG. 465.

*Palmar Side.*



DISTAL ROW OF LEFT CARPAL BONES, PROXIMAL ASPECT.

#### THE TRAPEZIUM.

**General Description.**—The Trapezium is the smallest bone in the carpus, except the small sesamoid articulating with the scapho-lunar. It is the first bone on the radial side of the distal row of the carpus (Figs. 465, 466), where it lies behind and to the radial side of the trapezoid, with its long axis running obliquely in a dorso-ulnar direction. It is crescentic in shape and presents five surfaces, proximal, dorsal, palmar, radial, and ulnar.

The proximal surface (Fig. 467) is nearly square, or slightly narrowed at the dorsal end. Its outer and inner margins are sharp and well defined. Its posterior margin passes into the rounded palmar surface. A faint ridge passing in a dorso-radial direction divides the proximal surface from the dorsal surface. The proximal surface is almost flat, and is marked by a slight groove which extends in a dorso-radial line at right angles to the main axis of the bone. It is covered with cartilage for articulation with the facet on the under surface of the process of the scapho-lunar.

FIG. 466.

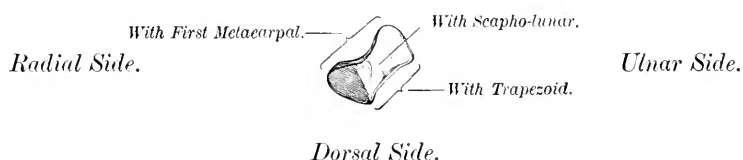


POSITION OF TRAPEZIUM.

The **dorsal surface** forms almost a right angle with the proximal surface. It is directed to the radial as well as to the dorsal side, and resembles the surface just described, but can be distinguished from it by its roughness and by the absence of the transverse groove. The radial border is straight. The ulnar border is sinuate, and the distal end is produced in a decided angle. The dorsal surface gives attachment to ligaments.

The **palmar surface** is very small and triangular, with the base of the triangle facing the scapho-lunar, and the apex, which is directed

FIG. 467.

*Palmar Side.*

LEFT TRAPEZIUM, PROXIMAL SURFACE.

distally, formed by the palmar termination of the sharp ridge which divides the radial from the ulnar surface. The surface faces inward and backward; it gives attachment to ligaments and to the flexor brevis pollicis muscle.

The **radial surface** (Fig. 468) is regularly crescentic in outline. Well-defined margins separate it from the dorsal surface in front, the

FIG. 468.

*Proximal Side.*

LEFT TRAPEZIUM, RADIAL SURFACE.

proximal surface above, and the palmar surface behind, and the sharp emarginate border below divides it from the ulnar surface. It is saddle-shaped, concave from above downward, and convex from before backward, and faces radially, distally, and to the palmar side. It articulates with the base of the first metacarpal.

The **ulnar surface** (Fig. 469) is also crescentic in outline, and is

directed dorsally and to the ulnar side. It is divided into two articular facets by a pit in which is inserted a ligament from the trapezoid.

The **upper facet**, which is long and narrow, is bounded above by the proximal surface, in front by the dorsal surface, behind by the

FIG. 469.

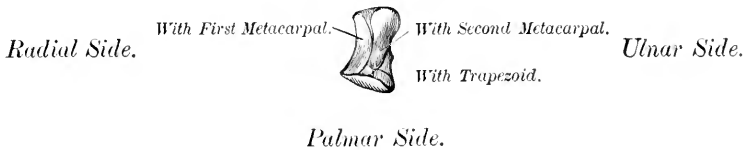
*Proximal Side.*

LEFT TRAPEZIUM, ULNAR SURFACE.

palmar surface, and below by a part of the lower border of the radial surface. It articulates with a facet of corresponding shape on the radio-palmar surface of the trapezoid.

The **lower facet** is nearly square, and does not occupy the same plane with the upper facet, but faces rather in a dorso-palmar direction.

FIG. 470.

*Dorsal Side.*

LEFT TRAPEZIUM, DISTAL ASPECT.

It articulates with the radial side of the head of the second metacarpal.

**Nomenclature.**—Trapezium means an irregular four-sided figure, and is derived from the Greek *trapeze*, a table. *Os multangulum magnus* (the larger many-angled bone) is in general use among European anatomists. The Germans translate these terms into *Trapezbein* and *das grosse vieleckige Bein*. In the French we find *le trapèze*. The trapezium is *carpale I*. in comparative anatomy.

**Determination.**—If the proximal surface be held upward and the dorsal surface toward the student, the radial side will point to the side to which the bone belongs.

**Articulation.**—The trapezium articulates with the scapho-lunar

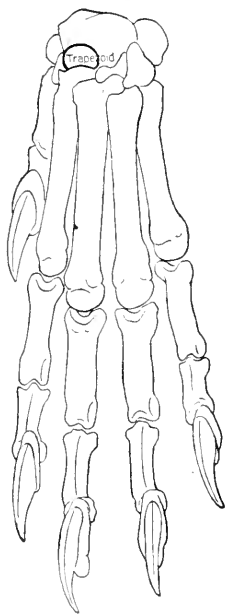
above, the trapezoid and second metacarpal in front and within, and the first metacarpal without and behind. It is attached by its palmar surface to the palmar end of the vertical plate of the magnum.

**Ossification.**—The trapezium is developed from one centre of ossification.

### THE TRAPEZOID.

**General Description.**—The trapezoid is the second bone on the radial side of the distal row (Fig. 471). Next to the trapezium it is

FIG. 471.



POSITION OF TRAPEZOID.

the smallest bone of the carpus. It may be easily distinguished by its small size and compressed, plate-like form. It lies distal to the scapho-lunar and on the ulnar side of the trapezium. When seen from above or below, its outline is that of a square with one angle directed to the palmar side, with the opposite dorsal angle rounded and the ulnar angle truncated.

It exhibits nearly flat and parallel proximal and distal surfaces, a straight radio-palmar surface, which forms right angles with the straight and parallel radio-dorsal and palmo-ulnar surfaces, a convex dorsal surface, which meets the radio-dorsal surface and the sharp dorso-ulnar border at angles of forty-five degrees, and, finally, a dorso-ulnar surface, formed by the cutting off of the ulnar angle of the square and converted into a sharp border by the sloping downward of the proximal surface and the turning 'up of the distal surface. This border forms angles of forty-five degrees with the dorsal and palmo-ulnar surfaces.

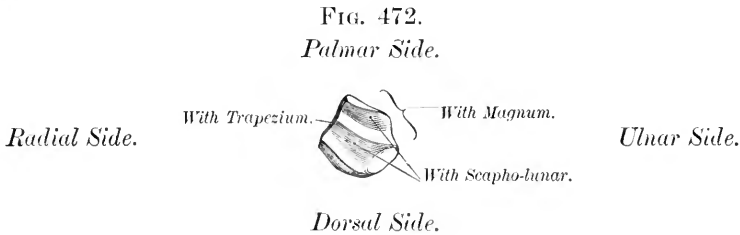
The **proximal surface**, which exhibits the general outline of the bone, is divided into two parts by a ridge running parallel to the radio-dorsal and palmo-ulnar borders until it reaches the dorsal third of the surface, where it curves to the ulnar side in a distal and palmar direction to meet the angle formed by the meeting of the dorsal surface and dorso-ulnar border.

The outer of these parts is smaller, narrower, and more elevated than the inner. It is principally occupied by an elongated, crescentic, articular facet, which is gently concave from side to side and joins a

facet on the under surface of the scapho-lunar. The proximal surface on the radial side of this facet is rough and convex; it turns down into the radio-dorsal and dorsal surfaces.

The inner larger portion of the proximal surface is converted into a deeply concave crescentic articular surface, which runs forward and inward and slopes down in front to meet the distal surface, forming, as already explained, the sharp dorso-ulnar border. This facet is separated behind from the palmo-ulnar surface by an elevated crest. It also articulates with the facet on the distal surface of the scapho-lunar.

The **radio-dorsal surface** is slightly convex from before backward. It is longer than high; in outline triangular, the apex of the triangle at the radio-palmar angle and the base passing by a convexity into the dorsal surface. It is slightly roughened, and gives attachment to ligaments.



LEFT TRAPEZOID, PROXIMAL SURFACE.

The **dorsal surface** is also triangular; the base of the triangle is applied to the base of the triangular radio-dorsal surface, and the apex reaches the outer end of the dorso-ulnar border. It is convex from side to side, and slopes upward and backward to pass into the dorsal end of the proximal surface.

The **palmo-ulnar surface** is twice as long as high. Its palmar border is straight, its proximal and distal borders slightly arcuate, meeting in front at quite an acute angle. It is almost flat, and rough, and is bound by strong ligaments to the rough surface on the outer side of the magnum.

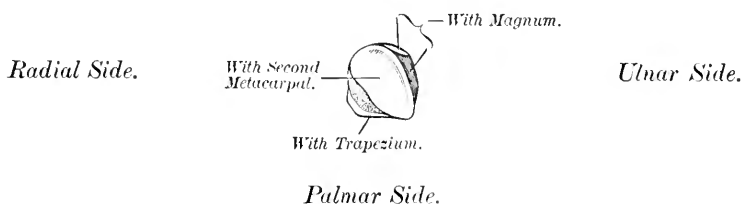
The **dorso-ulnar border** is about half as long as the palmo-ulnar surface. It is faintly emarginate, and limits the deep articular concavity on the proximal surface.

The **radio-palmar surface** is also twice as long as high, and is nearly flat, except at its radio-distal angle, which slopes downward and forward into the distal surface. Its ulnar border is straight, and runs

slightly to the radial side as well as upward. The proximal border has a concavity on its ulnar half, the end of the concave articular facet on the proximal surface, and slopes downward and outward to the radial angle. The distal border is straight and parallel with the corresponding part of the proximal border for a short distance from the ulnar side; it then curves upward and is lost as this surface passes into the distal surface. The entire radio-palmar surface is smooth, and covered with cartilage for articulation with a facet on the inner surface of the trapezium.

The **distal surface** (Fig. 473) has the same general outline as the proximal surface. It exhibits a central oval surface, which is gently

FIG. 473.  
*Dorsal Side.*



LEFT TRAPEZOID, DISTAL SURFACE.

concave for articulation with the base of the second metacarpal. This surface is bounded in front and on the radial side by the curved dorsal and radio-dorsal borders. A straight, low ridge cuts off along the dorso-ulnar border a small articular facet which slopes upward and inward; it articulates with a facet on the dorsal end of the radial side of the proximal surface of the process on the horizontal plate of the magnum. The palmo-ulnar border of the larger facet runs to the radial and palmar sides and meets the radio-palmar border at a right angle. The latter border is straight for about half its length, and then ends at a pit for the insertion of a ligament from the trapezium. At this point the distal surface curves abruptly upward into the radio-palmar surface and forms part of the articular surface for the trapezium.

**Nomenclature.**—Trapezoid is formed by the union of *trapezium*, and *cides*, like. Its common synonyms are *Os multangulum minus*, *carpale II.*, *das kleine vieleckige Bein*, *das Trapezoidbein*, *le trapézoïde*.

**Determination.**—When the proximal surface is held upward and



the dorsal surface toward the student, the straight end of the ridge on the proximal surface points to the side to which the bone belongs.

**Articulation.**—The trapezoid articulates with the scapho-lunar above, with the magnum on the inside, with the second metacarpal below, and with the trapezium on the outside. Its palmar angle does not show on the palmar surface of the hand; the trapezium and magnum come together and exclude it.

**Ossification.**—The trapezoid develops from one centre of ossification.

**Muscular Attachment.**—The palmar surface of the trapezoid affords attachment to ligaments to which is attached the origin of the flexor brevis pollicis.

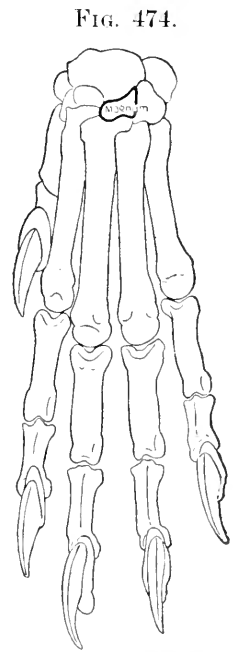
### THE MAGNUM.

**General Description.**—The Magnum, or os magnum, is the central bone of the distal row of the carpus, and lies between the trapezoid and the unciform, above the third and fourth metacarpals, and below the scapho-lunar (Fig. 474). In shape it is very irregular, but for purposes of description may be divided into two parts, a thin horizontal plate, or body, and a vertical plate, or head. The horizontal plate, or body, is rectangular, twice as long in the dorso-palmar direction as it is wide in the radio-ulnar diameter.

The vertical plate, or head, is placed at right angles to the body, but attached obliquely across its proximal surface, so that its dorsal end is at the ulnar side and its palmar end at the radial side, thus exposing two triangles of the proximal surface of the body, one at the radio-dorsal angle and another at the ulno-palmar angle. The proximal border of the head is strongly arched from before backward.

The magnum as a whole presents on examination six surfaces, proximal, dorsal, radial, ulnar, palmar, and distal.

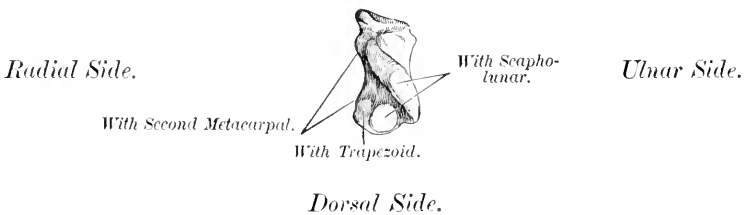
The proximal surface (Fig. 475) of the bone consists of three distinct parts: (1) the radio-dorsal triangle of the body mentioned above, on the outer side of which is a small square facet for articulation with the dorsal end of the oblique ridge on the distal surface of the scapho-



POSITION OF MAGNUM.

lunar; (2) the rounded convex margin of the head, which fits into the deep oblique groove on the under surface of the scapho-lunar; and (3) the ulno-palmar triangle, which is rough and gives attachment to ligaments. The radial and ulnar borders of this surface are nearly

FIG. 475.

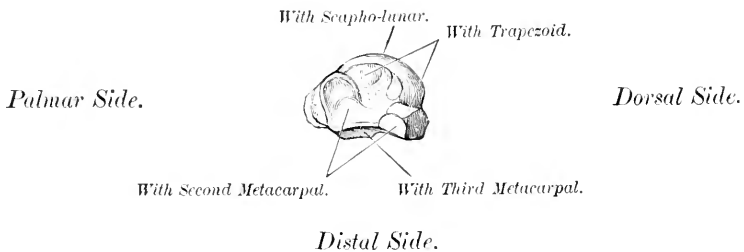
*Palmar Side.*

LEFT OS MAGNUM, PROXIMAL SURFACE.

parallel, and at right angles with the dorsal border. The palmar border is obliquely truncate, so that the radio-palmar angle appears as though produced.

The dorsal surface (Fig. 460) extends across the bone, but is only one-half as high as it is wide. At its ulnar side it passes upward into the dorsal edge of the head. Its radial end is pointed and somewhat higher than the rest of the surface. The lower part on the body is rough, for ligamentous attachment. The part on the head is smooth, covered with cartilage, and articulates with the scapho-lunar.

FIG. 476.

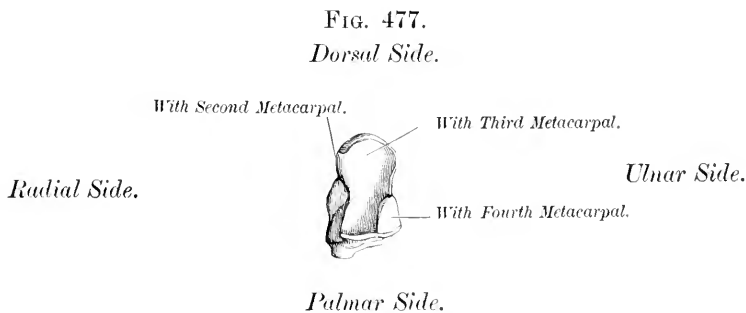
*Proximal Side.*

LEFT OS MAGNUM, RADIAL SURFACE.

The radial surface is bounded above by the arched border of the head, dorsally by a small vertical border, behind by the arcuate palmar border, and below by the straight or slightly emarginate distal border. The portion which belongs to the body appears as a process

and presents two small articular facets: (1) the narrower and lower facet on the front of the distal border, for the second metacarpal; (2) the upper square facet, for the trapezoid. On the portion of the radial surface which is on the head a curved facet for the scapho-lunar follows the superior border and joins the small facet on the upper or proximal surface. Behind these facets is a rough surface, to which the posterior part of the contiguous surface of the trapezoid is attached by a strong ligament. Below this surface, near the distal border, is a crescentic facet for the side of the base of the second metacarpal. It is separated from the facet which is placed on the side of the process for articulation with the second metacarpal by a small pit, into which is inserted a ligament from that bone. A small rough space is left free near the palmar border for the attachment of a ligament from the base of the metacarpal.

Almost the entire **distal surface** is occupied by a large oblong surface, which is concave and articulates with the base of the third meta-



LEFT OS MAGNUM, DISTAL SURFACE.

carpal. At the palmo-ulnar angle is a triangular facet for a part of the base of the fourth metacarpal. A groove separates the base of this facet and the palmar end of the surface for the third metacarpal from the palmar border of the distal surface proper, which is rough and produced into a process at its radio-palmar angle.

The triangular **palmar surface** is rough for ligamentous attachment, and faces backward and to the ulnar side.

The **ulnar surface** (Fig. 478) closely resembles the radial surface. It differs in having the process-like projection of the body at the palmar side. A narrow facet runs along the distal border from the point of the projection, and when it reaches the dorsal border becomes wider and turns up along the dorsal border and the anterior half of

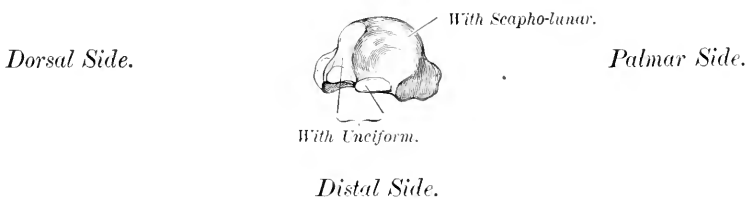
the curved proximal border. It articulates with a corresponding facet on the unciform. The posterior half of the proximal border is rounded and continuous with the proximal surface. Between the palmar border and these facets is a distinct pit, which is filled by a strong ligament from the unciform.

**Nomenclature.**—*Os magnum* is the great bone of the human carpus. *Os capitatum*, the bone with a head, is the European synonym. The Germans have *das Kopfbein*, and the French *le grand os*. In comparative anatomy the magnum is the *carpale III*.

**Determination.**—If the proximal surface be held upward and the dorsal surface toward the student, the produced radio-palmar angle will point to the side to which the bone belongs.

FIG. 478.

Proximal Side.



LEFT OS MAGNUM, ULNAR SURFACE.

**Articulation.**—The magnum articulates with the scapho-lunar on the proximal side, with the trapezoid and second metacarpal on the radial side, with the third and fourth metacarpal on the distal side, and with the unciform on the ulnar side. It is connected by ligament with the trapezium.

**Muscular Attachments.**—The palmar surface of the magnum affords attachment indirectly to the *flexor brevis pollicis* and *adductor pollicis* muscles.

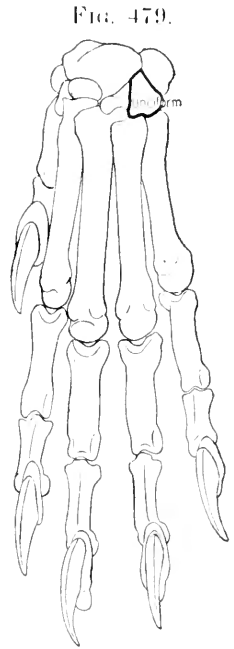
**Ossification.**—The magnum has one centre of ossification.

### THE UNCIFORM.

**General Description.**—The Unciform is placed on the ulnar end of the distal row (Fig. 479), and may be easily recognized by its characteristic shape, that of a wedge. It is narrow from side to side, and longer in its dorso-palmar and proximo-distal diameters. The apex of the wedge is truncate and forms the proximal surface. There are six surfaces.

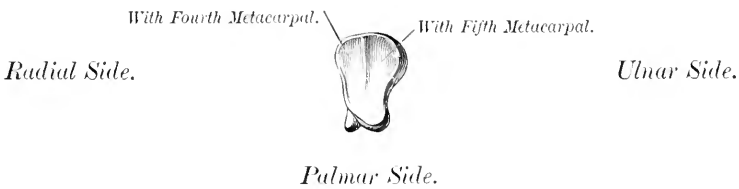
The **dorsal surface** (Fig. 484) presents the form of a truncated triangle, whereof the base is below and the apex is above. The outer or radial border is almost vertical, and is slightly emarginate. The ulnar border is straight, and runs downward and to the ulnar side for most of its extent, but before reaching the distal border bends sharply to the radial side. The distal border is transverse; the proximal border runs obliquely downward and to the radial side. The dorsal surface is gently convex from side to side and somewhat excavated above; it is everywhere slightly roughened for the attachment of ligaments.

The **distal surface** (Fig. 480) is pear-shaped, with the wide portion at the dorsal side and the narrow portion at the palmar side. It is strongly concave from before backward, and divided by a longitudinal low line into two nearly equal articular surfaces, which are slightly concave transversely and articulate with the bases of the fourth and fifth metacarpals. Its radial and dorsal borders are gently arcuate; its ulnar border is emarginate.



POSITION OF UNCIFORM.

FIG. 480.  
*Dorsal Side.*



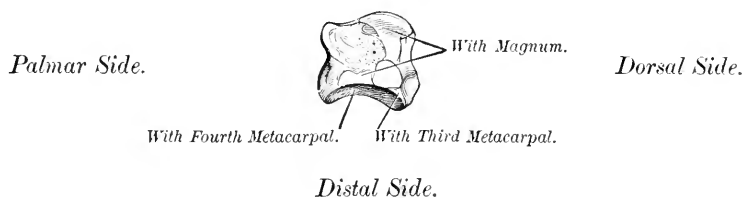
LEFT UNCIFORM, DISTAL SURFACE.

The **palmar surface** is rough and irregular for the attachment of ligaments. It is narrower than high, and is divided by a transverse groove into two nearly equal prominences.

The **radial surface** (Fig. 481) is almost square, but higher at the dorsal end than at the palmar end, and longer at the distal margin than at the proximal margin. Its proximal border is sinuate, arcuate at the dorsal end and emarginate behind. The dorsal and distal borders

are emarginate, and the palmar border is prolonged above and below by the two small prominences of the palmar surface. From a point dorsal to the centre back to the palmar border a large part of the radial surface is taken up with a rough depression wherein is attached the ligament from the magnum. Dorsal and distal to this pit is the L-

FIG. 481.

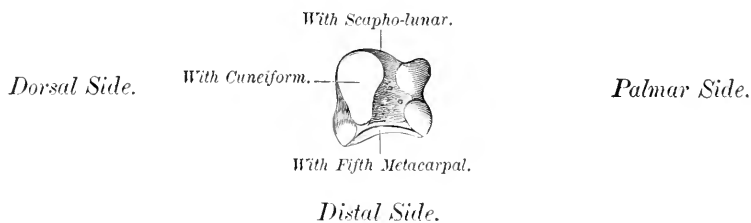
*Proximal Side.*

LEFT UNCIFORM, RADIAL SURFACE.

shaped articular surface for the magnum. The articular facet on the proximal surface for the scapho-lunar is visible along the proximal border, slightly in the dorsal half, but more largely on the palmar half.

The **ulnar surface** (Fig. 482) resembles the radial in shape. It differs from it in having the dorsal half covered with cartilage and

FIG. 482.

*Proximal Side.*

LEFT UNCIFORM, ULNAR SURFACE.

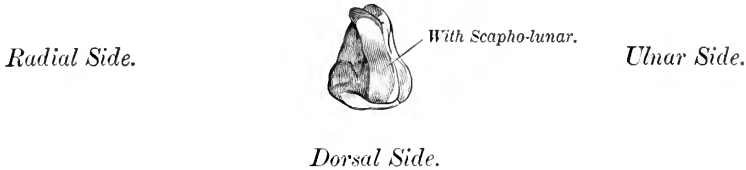
converted into a broad pear-shaped articular facet for the cuneiform. It is slightly concave from above downward and convex from before backward. The palmar half of the ulnar surface is rough and depressed for the attachment of the strong ligament from the palmar border of the radial surface of the cuneiform. The palmar border is swollen at each end.

The **proximal surface** (Fig. 483) is long and narrow and lies obliquely to the dorso-palmar axis of the bone, because it is directed from the dorsal to the radial as well as to the palmar side. It faces

in a radio-proximal direction. It is divided into two parts by the transverse depression seen at the junction of the middle and posterior thirds. The anterior or dorsal part is convex from before backward, and also slightly convex from side to side. The smaller palmar portion is slightly concave in both directions, and faces to the dorsal and radial sides as well as in a proximal direction. Both parts are covered with cartilage and articulate with a facet on the ulnar side of the distal surface of the scapho-lunar.

**Nomenclature.**—Unciform is from *uncus*, a hook, and *forma*, likeness, because of the shape of the human bone. The Latin name adopted by European anatomists is *os hamatum*, from *hamatus*, hooked.

FIG. 483.  
*Palmar Side.*



LEFT UNCIFORM, PROXIMAL SURFACE.

It is *das Hakenbein* of the Germans and *l'os crochu* of the French. The unciform is formed by the union of the *carpalia IV.* and *V.* of comparative anatomists.

**Determination.**—If the proximal side be held upward and the dorsal side toward the student, the palmar end of the proximal surface will point to the side to which the bone belongs.

**Articulation.**—The unciform articulates above with the scapho-lunar, on the ulnar side with the cuneiform, on the radial side with the magnum, and below with the fourth and fifth metacarpals.

**Ossification.**—The unciform has but one centre of ossification.

### THE METACARPUS.

**General Description.**—The Metacarpus forms the middle region of the hand, and therefore lies between the carpus, or wrist, above, and the phalanges, or fingers, below. (Fig. 484.)

It comprises five long bones,—the metacarpal bones of the thumb, the index, the middle, the ring, and the little finger,—which are numbered the **first**, the **second**, the **third**, the **fourth**, and the **fifth**





**metacarpal** respectively. The metacarpus presents two surfaces, the dorsal and the palmar, and two ends, the proximal, or upper, and the distal, or lower.

The **dorsal surface** is slightly convex from above downward, and decidedly convex from side to side; this convexity is much more evident on the radial, or thumb, side.

The **palmar surface** is concave from the radial to the ulnar side, and also slightly from the proximal to the distal end.

The **proximal end** is irregular, and is higher on the radial than on the ulnar side.

The **distal end** presents the form of a truncated triangle, inasmuch as the third and fourth metacarpals are longer than the second and fifth.

The constituent bones of the metacarpus are nearly parallel; they are contiguous at their upper ends and bound together by strong ligaments, but free below for the rest of their length. Inasmuch as the lower ends are wider than the shafts, spaces are left between the shafts, the so-called **interosseous spaces**, which are filled in part by interosseous muscles. The metacarpal of the thumb, the length whereof is only about one-third the length of the metacarpal of the index, is in a different plane from the others, so that its dorsal surface faces almost directly toward the radial side.

**Nomenclature.**—The term metacarpus is the Latin translation of the Greek *metacarpion* of Galen, a compound of *meta*, beyond, and *carpion*, the carpus. The old Latin name was *pecten manus*, because the separate bones looked like the teeth of a comb. It is known in German as *die Mittelhand*, and in French as *le métacarpe*.

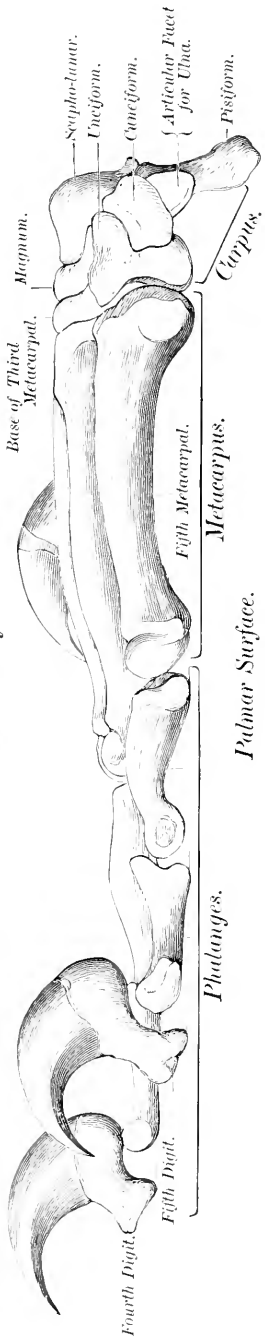
#### CHARACTERS COMMON TO ALL METACARPAL BONES.

**General Description.**—Every metacarpal consists of a proximal extremity, or **base**, a central part, or **shaft**, and a distal extremity, or **head**.

The metacarpal of the thumb differs so decidedly from the rest that it must be described separately. The following explanation applies, therefore, only to the other four.

The **Base** is irregularly cuboidal in shape, and is not divided from the shaft by a conspicuous neck. In every metacarpal it presents individual peculiarities in shape and in the arrangement of its prominences and depressions.

FIG. 485.  
*Dorsal Surface.*



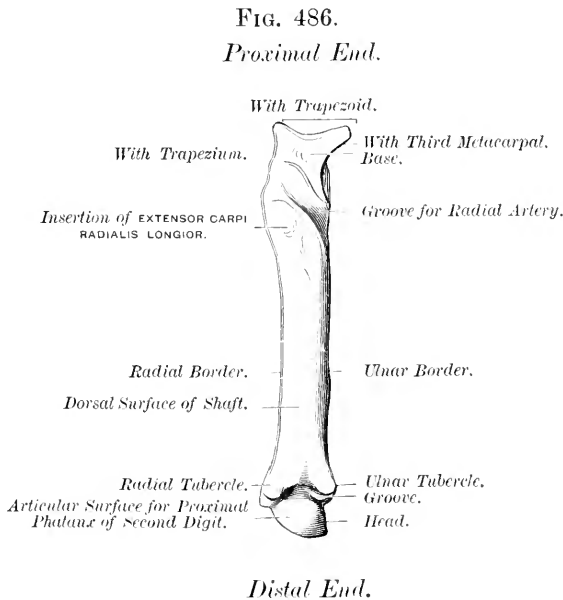
LEFT HAND, ULNAR SIDE.

The dorsal surface is flat or slightly convex, and passes into the shaft without any distinct line of separation. It is roughened for the attachment of ligaments.

The radial surface or the ulnar surface, or both surfaces, may have articular facets above for the contiguous metacarpal bones, and in some cases for the carpal bones also. These surfaces are rough below where strong ligaments are attached.

The palmar surface is produced at its proximal end into a hook-like process more or less marked, below which it is rough for the insertion of ligaments.

The Shaft comprises almost the entire bone. It is nearly cylindrical, and is six or eight times as long as wide. It is slightly convex on its dorsal side from the base to the head, and concave on the palmar side. On close examination it is seen to be not exactly cylindrical, but slightly prismatic, presenting three surfaces, a dorsal, a radio-palmar, and a palmo-ulnar, and three borders, a radial, an ulnar, and a palmar.



SECOND LEFT METACARPAL, DORSAL SURFACE.

The dorsal surface (Fig. 486) is almost flat at the proximal and distal ends, but for most of its length it is convex from side to side. It passes without a break into the corresponding surface of the base, and it widens out below and presents at each border a prominent tubercle for the attachment of ligaments and the tendons of muscles.

Between these tubercles is a longitudinal groove which is lost in the transverse constriction separating the head from the shaft on the dorsal and lateral surfaces. The lateral borders of the dorsal surface are nearly parallel, and are not very well defined, so that the radio-palmar and palmo-ulnar surfaces are almost continuous with the dorsal.

The **lateral surfaces** (Fig. 485) are convex and roughened above, where they pass into the lateral surfaces of the base. At their distal ends they are separated dorsally from the head by a continuation of the constriction already mentioned, but the palmar half passes on each side of the palmar border into the palmar articular surfaces of the head. The palmar border, well defined above, fades out toward the middle of the shaft, but sometimes appears again faintly at the distal end.

The **Head** is spheroidal in shape. It is separated from the shaft dorsally and at the dorsal part of the sides by a well-marked transverse groove. Its dorsal surface is rounded; its distal and palmar surfaces (Fig. 453) are divided by a sharp longitudinal ridge into two parts. The ridge begins on the distal surface and ends behind abruptly at its highest part. The parts on either side of the ridge are convex from before backward and concave from side to side, and are articular surfaces for the bases of the prismatic sesamoid bones, which protect the palmar aspect of the metacarpo-phalangeal joints. The rounded dorsal part of the distal surface of the head is covered with cartilage, and is contained in the concavity in the base of the proximal phalanx of the digit.

**Nomenclature.**—The metacarpal bones are called *ossa metacarpi* or *ossa metacarpalia*, and are numbered from the radial to the ulnar side—from the first metacarpal, or *os metacarpale primum*, to the fifth metacarpal, or *os metacarpale quintum*. In German they are *die Mittelhandknochen*, in French *les métacarpiens*.

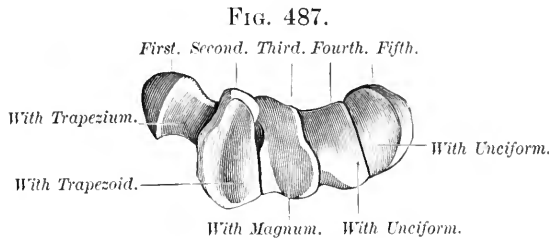
#### THE FIRST METACARPAL BONE.

**General Description.**—The metacarpal of the thumb differs from all the others by its smaller size and by the shape and direction of its base and head.

Its **Base** is flat on the palmar aspect and rounded on the dorsal and radial sides.

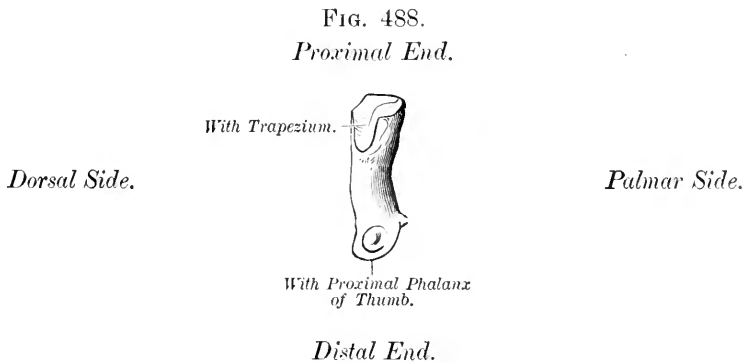
Its **proximal surface** (Fig. 487) is divided into two parts by a sharp line running obliquely to the ulnar and dorsal sides. The

outer of these parts is prominent and rounded for the attachment of the tendon of the extensor ossis metacarpi pollicis. It passes into the radial surface and the radial side of the dorsal surface. The inner part is an articular surface for the radial surface of the trapezium;



THE METACARPAL BONES, PROXIMAL ASPECT.

it is longer than wide, saddle-shaped, deeply concave from side to side, and convex from above downward. The palmar margin of this surface is sharp and slightly emarginate. Its lateral margin is sharp and elevated. Below, it is lost on the ulnar aspect of the dorsal sur-



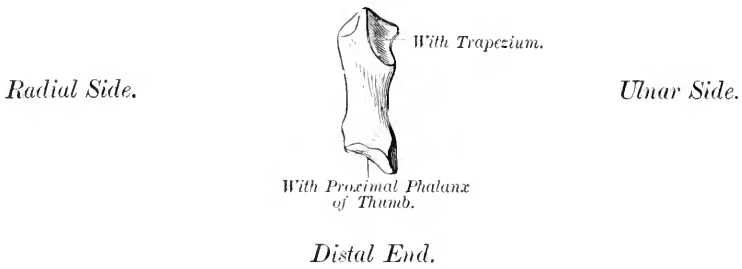
• FIRST LEFT METACARPAL, ULNAR SURFACE.

face of the shaft of the bone (Fig. 488). When the bone is held with its dorsal surface upward the articular surface faces upward and to the ulnar side, but when the bone is in position, as the dorsal surface looks radially, the facet faces toward the wrist and the back of the hand. On the ulnar side of the base is a rough surface, in which is inserted the ligament which binds the bone to the contiguous side of the second metacarpal.

The **Shaft** is flattened from above downward.

Its **dorsal surface** (Fig. 489) is convex in both directions; its radio-palmar and palmo-ulnar surfaces are concave in the proximo-distal line

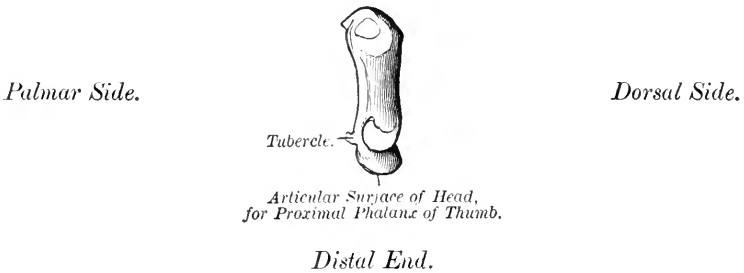
FIG. 489.

*Proximal End.*

FIRST LEFT METACARPAL, DORSAL SURFACE.

and convex from side to side. The ulnar part of the palmo-ulnar surface affords origin to the first dorsal interosseous muscle. Its radial border is much shorter than the ulnar border, and the palmar border is not well defined.

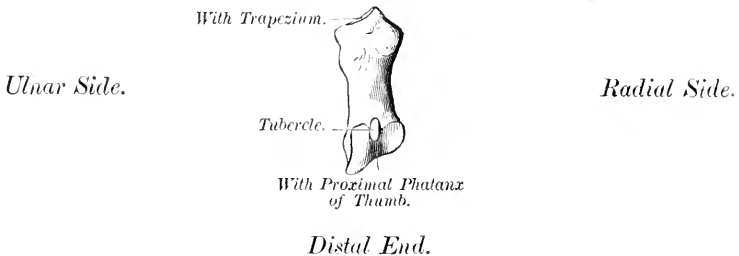
FIG. 490

*Proximal End.*

FIRST LEFT METACARPAL, RADIAL SURFACE.

The **Head** consists of a cylindrical articular surface placed so obliquely to the shaft of the bone that it faces equally in the distal and the radial direction. On the palmar surface (Fig. 491) where the

FIG. 491.

*Proximal End.*

FIRST LEFT METACARPAL, PALMAR SURFACE.

articular surface passes into the palmar surface of the shaft, in the middle line, is a little sharp tubercle, and on either side a faint longitudinal concavity for the base of the sesamoid bone.

**Determination.**—When the dorsal side is held upward and the proximal side toward the student, the long side of the bone is on the side to which the bone belongs.

**Articulation.**—The metacarpal of the thumb articulates with the trapezium above and its own proximal phalanx below, and is fastened to the side of the second metacarpal by ligament.

**Muscular Attachments.**—The metacarpal of the thumb offers attachment by the radial side of the base to the tendon of the *extensor ossis metacarpi pollicis*, and by the palmo-ulnar surface to the *first dorsal interosseous muscle*.

**Ossification.**—It is developed by two centres, one for the base and one for the shaft.

#### THE SECOND METACARPAL BONE.

**General Description.**—The second metacarpal is about three times as long as the first, but very little stouter.

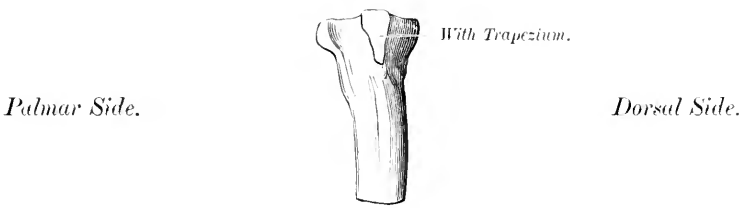
The **Base** is prismatic in shape, broad in front and very narrow behind. Its long axis is not in line with the long axis of the shaft, but directed toward the ulnar side (Fig. 486).

The inclination is made more apparent by the groove for the radial artery, which is situated on the dorsal surface of the shaft; it passes obliquely downward from the radial to the ulnar side, and is continued on the ulnar surface downward to the palmar side. The long dorso-palmar diameter of the base is directed obliquely to the ulnar and palmar sides.

Its **proximal surface** (Fig. 487) is triangular, and convex from before backward. From side to side it is at first slightly convex on the ulnar side and then strongly concave from the middle to the radial margin, the dorsal part of which rises to a sharp crest. This surface articulates with the distal surface of the trapezoid.

On the **radial surface** of the base (Fig. 492) near the external border is an elongated oval facet for articulation with the facet on the distal part of the ulnar surface of the trapezium. Behind this facet the bone is rough for the attachment of ligaments and interosseous muscles.

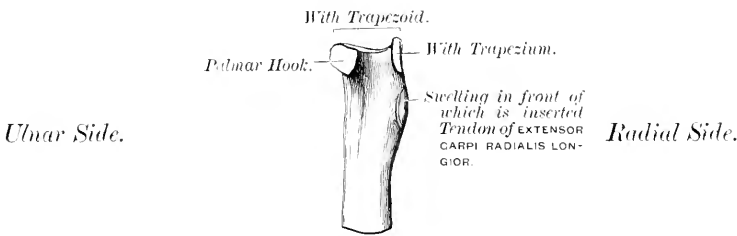
FIG. 492.  
*Proximal End.*



SECOND LEFT METACARPAL, RADIAL SURFACE OF BASE AND  
PART OF SHAFT.

The **palmar angle** of the base (Fig. 493) is a prominent hook-like process for the attachment of the first palmar interosseous muscle.

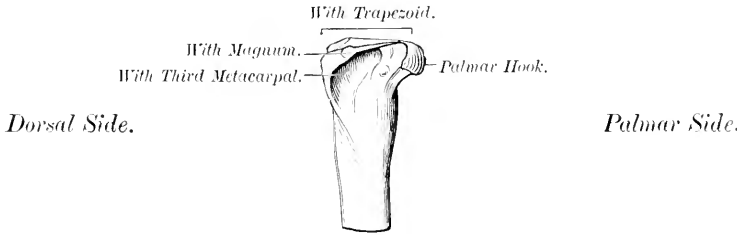
FIG. 493.  
*Proximal End.*



SECOND LEFT METACARPAL, PALMAR SURFACE OF BASE AND  
PART OF SHAFT.

The proximal border of the **ulnar surface** of the base (Fig. 494) appears as a ridge, which overhangs the surface lying below. The

FIG. 494.  
*Proximal End.*



SECOND LEFT METACARPAL, ULNAR SURFACE OF BASE AND  
PART OF SHAFT.

ridge is sharp in front and prominent and rounded behind. Between these two parts is a roughened pit for the insertion of the ligament which binds the bone to the magnum. The ridge extends over the



radial side of the proximal surface of the base of the third metacarpal, and articulates for nearly its whole length with two facets on the radial side of the magnum. The concave surface below this margin receives a projection from the contiguous side of the base of the third metacarpal. Below this concavity, and down to the oblique groove for the radial artery, the surface is rough for the attachment of the interosseous ligament.

The **Shaft** does not present any striking peculiarity. Its radial border is concave. On its dorsal surface, which faces slightly to the radial side, just below the oblique groove, is a swelling where the tendon of the extensor carpi radialis longior is inserted. The proximal part of the **palmar surface** gives attachment to the first palmar interosseous and the adductor pollicis, and along the radial side of the same surface arise the first dorsal interosseous and adductor pollicis muscles. On the palmar side of the **ulnar border** a short distance below the base is the point of insertion of the flexor carpi radialis muscle.

The **Head** differs from the heads of the third and fourth metacarpals in being somewhat flattened on the ulnar side and presenting on the radial side a prominence which is continuous with the tubercle at the end of the lateral border of the shaft by passing behind the lower end of the transverse groove which separates the head from the shaft.

**Determination.**—The second metacarpal may be distinguished from the others by the oblique position of the base. When the bone is held with the dorsal surface upward and the proximal surface toward the student, the base points to the side to which the bone belongs.

**Articulation.**—The second metacarpal articulates on the radial side with the first metacarpal and with the trapezium; above, with the trapezoid; on the ulnar side, with the magnum and the third metacarpal; and below, with the proximal phalanx of the digit.

**Muscular Attachments.**—The second metacarpal offers attachment by the dorsal surface to the **extensor carpi radialis longior**; by the palmar surface to the **first dorsal interosseous**, the **first palmar interosseous**, the **adductor pollicis**, and the **flexor carpi radialis**.

**Ossification.**—The second metacarpal is developed from two centres, one for the shaft and one for the head.

### THE THIRD METACARPAL BONE.

**General Description.**—The third metacarpal is about one-sixth longer and somewhat stouter than the second. It is slightly longer but not stouter than the fourth.

The **Base**, unlike the base of the second, is directly continuous with the shaft, and lies in the long axis of the entire bone. It may be distinguished from the bases of all the others by the shape of its proximal surface (Fig. 487), which is L-shaped and consists of two parts: (1) a rectangular portion lying on the ulnar side and extending from the dorsal to the palmar aspect, and (2) a sharp triangular part directed transversely from the dorsal end of the first part.

The first or ulnar part is rather more than twice as long in its dorso-palmar diameter as it is wide from side to side. Its dorsal border is rounded and its ulnar border is sinuate, arcuate dorsally and then faintly emarginate; it terminates at its palmar end by being directed obliquely to the radial and palmar sides and meeting the radial border in a point. The radial border begins behind at the palmar angle and is directed for a distance obliquely dorsally and to the radial side. It then bends at an angle and runs directly forward until it reaches the base of the triangular second part, where it may be said to be continued forward as a groove which separates the two parts and finally ends in the rounded dorsal border. This first part of the proximal surface is convex from before backward. In the transverse direction it is convex at first on the ulnar side and then becomes slightly concave where it approaches the triangular second part. It does not face directly proximally, but is inclined to the radial side. It is covered with cartilage, and articulates with a facet on the distal surface of the magnum. Its radio-palmar portion is slightly overlapped by the distal surface of the hook-like palmar part of the base of the second metacarpal.

The second or radial part appears as a process of the first part, and is separated from it by a notch in front and by a slight groove above. The groove runs obliquely backward and to the ulnar side, and is wider in front than behind, so that the process appears as a triangle with its longer side on the palmar aspect and the other two nearly equal sides directed forward to the dorsal and transversely to the ulnar side respectively. Its surface is slightly convex in both directions, and faces to the radial side as well as to the proximal side;

it fits into the depression under the dorsal part of the ridge on the ulnar side of the base of the second metacarpal.

The **ulnar surface** of the base (Fig. 495) presents on the proximal edge a distinct convex ridge which is somewhat wider in front than behind. The dorsal wider part presents an articular facet for the



THIRD LEFT METACARPAL, ULNAR SURFACE OF BASE AND  
PART OF SHAFT.

radial side of the unciform; under this ridge is a rough depression for a portion of the base of the fourth metacarpal, and below this again a rougher area for the attachment of the interosseous ligament.

The **palmar surface** (Fig. 496) begins on the palmar angle of the proximal surface, is continued downward, and is lost on the palmar border of the shaft. It is prominent, hook-like, narrow, and convex;



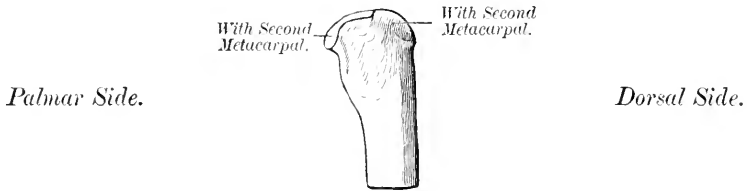
THIRD LEFT METACARPAL, PALMAR SURFACE OF BASE AND  
PART OF SHAFT.

above, it affords attachment for the ligaments, and below gives origin to the second palmar interosseous muscle.

The **radial surface** (Fig. 497) presents on its dorsal third the projecting part described above, behind which it is rough and concave from before backward. This concavity is filled by the interosseous ligament from the ulnar side of the base of the second metacarpal.

At the lower part of this surface of the shaft is an oblique groove running downward and backward and applied to the corresponding groove on the ulnar surface of the second metacarpal, forming with it a canal for the radial artery as it runs through from the dorsal to the palmar surface of the hand.

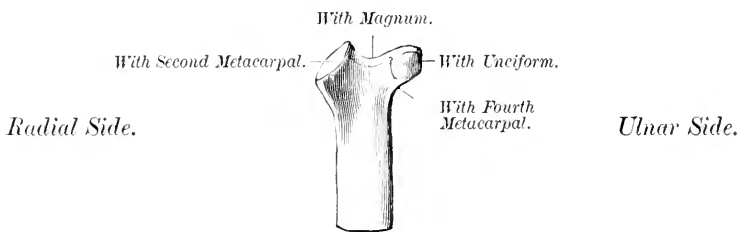
FIG. 497.  
*Proximal End.*



THIRD LEFT METACARPAL, RADIAL SURFACE OF BASE AND PART OF SHAFT.

The dorsal surface of the base (Fig. 498) is continuous with the dorsal surface of the shaft, and presents a depressed area which begins widely above at the notch separating the two parts of the proximal surface and fades out in a point below. On the radial side of this depression is inserted the tendon of the extensor carpi radialis brevior muscle.

FIG. 498.  
*Proximal End.*



THIRD LEFT METACARPAL, DORSAL SURFACE OF BASE AND PART OF SHAFT.

The **Shaft** presents few peculiarities. It is straighter than the shaft of the other metacarpals, and its widest part is at the middle. The palmar border is but faintly indicated, and gives origin in its upper part to the second palmar interosseous muscle. To the radial and ulnar sides of the shaft are attached the second and the third dorsal interosseous respectively.

The **Head** differs from the head of the second metacarpal in being transversely symmetrical.

**Determination.**—The third metacarpal can be easily recognized by its L-shaped proximal surface. When the bone is held with the dorsal surface upward and the proximal surface toward the student, the prominent hook-like projection on the ulnar side of the base points to the side to which the bone belongs.

**Articulation.**—The third metacarpal articulates with the magnum above, with the unciform and fourth metacarpal on the ulnar side, with the second metacarpal on the radial side, and with its own proximal phalanx below.

**Muscular Attachments.**—On the dorsal surface of the base is attached the **extensor carpi radialis breviar**; to the palmar border, the **second palmar interosseous**; and to the radial and ulnar sides of the shaft, the **second** and the **third dorsal interosseous** respectively.

**Ossification.**—The third metacarpal is developed from two centres of ossification, one for the shaft and one for the head.

#### THE FOURTH METACARPAL BONE.

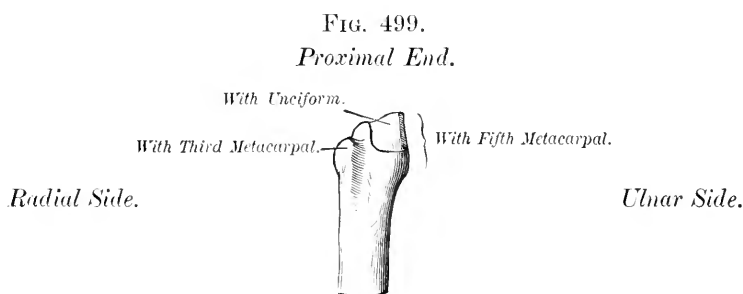
**General Description.**—The fourth metacarpal resembles the third in many particulars; it is very little shorter, and possibly somewhat stouter.

Its **Base** presents the distinguishing characteristics. As in the third metacarpal, the **proximal surface** consists of two parts, a rectangular ulnar part and a triangular radial part.

The ulnar part is three times as long as it is wide, and convex from before backward; it slopes slightly to the radial side and articulates with the distal surface of the unciform and at the radio-palmar angle slightly with the magnum and the third metacarpal. The radial part is joined to the dorsal half of the radial side of the ulnar part, and is directed obliquely to the dorsal and radial sides. It is convex in both directions, and separated from the first part by a groove which is wider in front than behind; it articulates with the ulnar surface of the base of the third metacarpal.

The proximal surface as a whole differs from that of the third metacarpal in possessing a truncate palmar border and a straight ulnar border, and in sloping without any distinct dorsal border into the dorsal surface of the shaft. While the highest part of the proximal

surface of the third metacarpal is near the dorsal border, the highest point of that surface in this bone is behind the middle. The radial part of the proximal surface of this bone is much lower than the ulnar



FOURTH LEFT METACARPAL, DORSAL SURFACE OF BASE AND  
PART OF SHAFT.

part (Fig. 499), and has the appearance of a small shelf, while in the third metacarpal the radial portion is as high as the general proximal surface.

The **ulnar surface** of the base (Fig. 500) does not project beyond the ulnar side of the shaft, otherwise it closely resembles the corresponding surface of the third metacarpal by presenting along the



FOURTH LEFT METACARPAL, ULNAR SURFACE OF BASE AND  
PART OF SHAFT.

proximal border a ridge which is wider behind than in front, and, near the dorsal border, a crescentic pit which, like the ridge, is covered with cartilage and articulates with the radial surface of the base of the fifth metacarpal. Behind this pit the ulnar surface is rough for the attachment of ligaments.

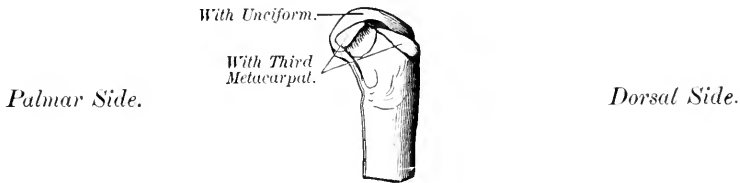
The **radial surface** (Fig. 501), below and behind the radial part of the proximal surface, is convex and rough for ligaments.

The **palmar hook** (Fig. 502) is broader than in the third metacarpal, as is the rough space below it.

The **Shaft** and **Head** present no peculiarities.

**Determination.**—When the bone is held with the dorsal surface upward and the proximal surface toward the student, the shelf-like radial part of the proximal surface of the base will serve to distinguish the bone from the other metacarpals, and the straight ulnar border is on the side to which the bone belongs.

FIG. 501.  
*Proximal End.*

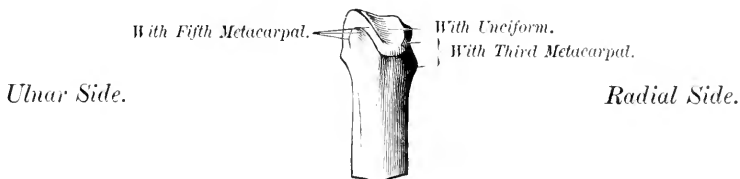


FOURTH LEFT METACARPAL, RADIAL SURFACE OF BASE AND PART OF SHAFT.

**Articulation.**—The fourth metacarpal articulates above with the magnum and unciform, on the radial side with the third metacarpal, on the ulnar side with the fifth metacarpal, and below with the proximal phalanx of its own digit.

**Muscular Attachments.**—The palmar aspect of the shaft gives origin near the base to the **third palmar interosseous**, and along the ulnar side to the **fourth dorsal interosseous**. A strong ligament from

FIG. 502.  
*Proximal End.*



FOURTH LEFT METACARPAL, PALMAR SURFACE OF BASE AND PART OF SHAFT.

the radial tip of the head of the pisiform is inserted into the proximal end of the shaft at the ulnar side of the palmar aspect, and may be regarded as the continuation of the tendon of the **flexor carpi ulnaris** muscle.

**Ossification.**—The fourth metacarpal is developed from two centres, one for the head and one for the shaft.

### THE FIFTH METACARPAL BONE.

**General Description.**—The fifth metacarpal is one-third shorter than the third, and about one-sixth shorter than the second. Its peculiarities lie in the shape of the base, in the shaft, and in the head.

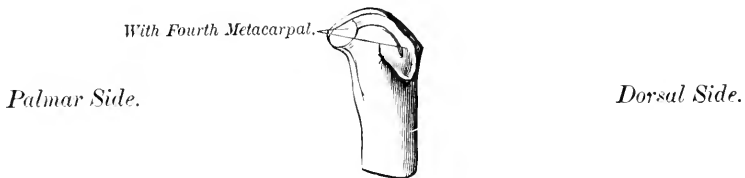
The **Base** differs from that of all the others in having no articular surface on the ulnar side, as it is the last bone on that side of the hand.

The **proximal surface** is three times as long as it is wide, strongly convex from before backward, and flat from side to side. Its radial border is sharp and straight; the ulnar border is curved, and meets the radial border in front and behind at angles, of which the palmar is the more obtuse. It faces directly upward, but its long axis is directed backward and to the radial side. Its ulnar border passes without a sharp break into the roughened tuberosity of the ulnar surface of the base. Almost the entire proximal surface is occupied by a facet, which articulates with the ulnar side of the distal surface of the unciform.

The **radial surface** of the base (Fig. 503) lies in a plane at right angles to the plane of the proximal surface. Its upper border is

FIG. 503.

*Proximal End.*



FIFTH LEFT METACARPAL, RADIAL SURFACE OF BASE AND PART OF SHAFT.

strongly arcuate, following the dorso-palmar curve of the proximal surface and passing into the dorsal side of the radial border of the shaft. The palmar side forms a prominent hook, under which it is continuous with the palmar border of the shaft.

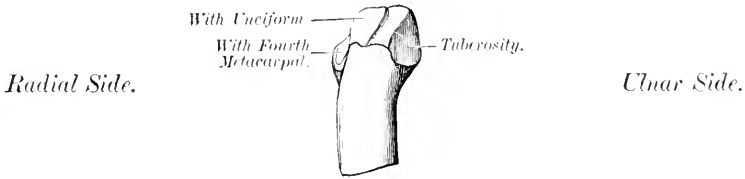
The upper part of the surface is flat, and is a crescentic articular facet for the contiguous side of the fourth metacarpal. This facet is wider behind than in front, where it passes to the dorsal side of a sharp ridge, which runs from the surface in an oblique direction downward and forward and fits into the depression on the ulnar side of the base of the fourth metacarpal. Below and behind the ridge the surface is convex for the attachment of ligaments.



The dorsal surface of the base (Fig. 504) is convex from side to side, slightly roughened, and passes into the corresponding surface of the shaft.

FIG. 504.

*Proximal End.*

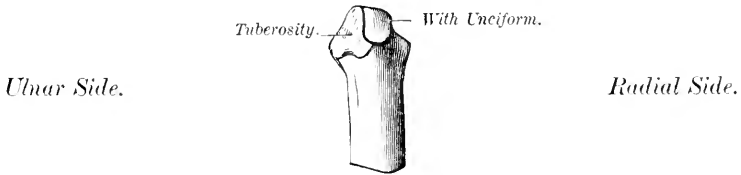


FIFTH LEFT METACARPAL, DORSAL SURFACE OF BASE AND PART OF SHAFT.

The palmar surface (Fig. 505) consists of the hook-like extension of the proximal surface, and an inferior rough space which is continuous with the back of the shaft.

FIG. 505.

*Proximal End.*

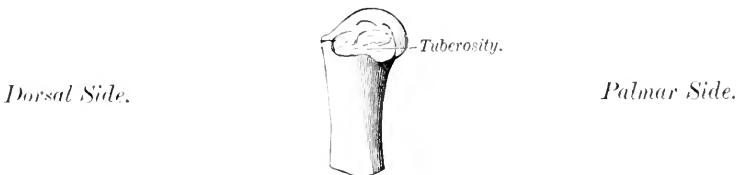


FIFTH LEFT METACARPAL, PALMAR SURFACE OF BASE AND PART OF SHAFT.

The ulnar surface (Fig. 506) is convex in both directions; it forms a rounded tuberosity, which is rough for the attachment of ligaments and the extensor carpi ulnaris muscle.

FIG. 506.

*Proximal End.*



FIFTH LEFT METACARPAL, ULNAR SURFACE OF BASE AND PART OF SHAFT.

On the **Shaft** of the fifth metacarpal the dorsal surface faces to the ulnar side as well as forward. The palmar aspect gives origin

near the base to the flexor brevis minimi digiti, or fourth palmar interosseous; it affords insertion distally to the opponens minimi digiti.

The **Head** is flattened on the radial side, and on the ulnar side presents a prominence like that on the radial side of the head of the second metacarpal.

**Determination.**—The rounded ulnar side of the bone distinguishes this metacarpal from all others. When the bone is held with the dorsal side upward and the proximal end toward the student, the rough tuberosity on the base points to the side to which the bone belongs.

**Articulation.**—The fifth metacarpal articulates with the unciform above, with the fourth metacarpal on the radial side, and with its own phalanx below.

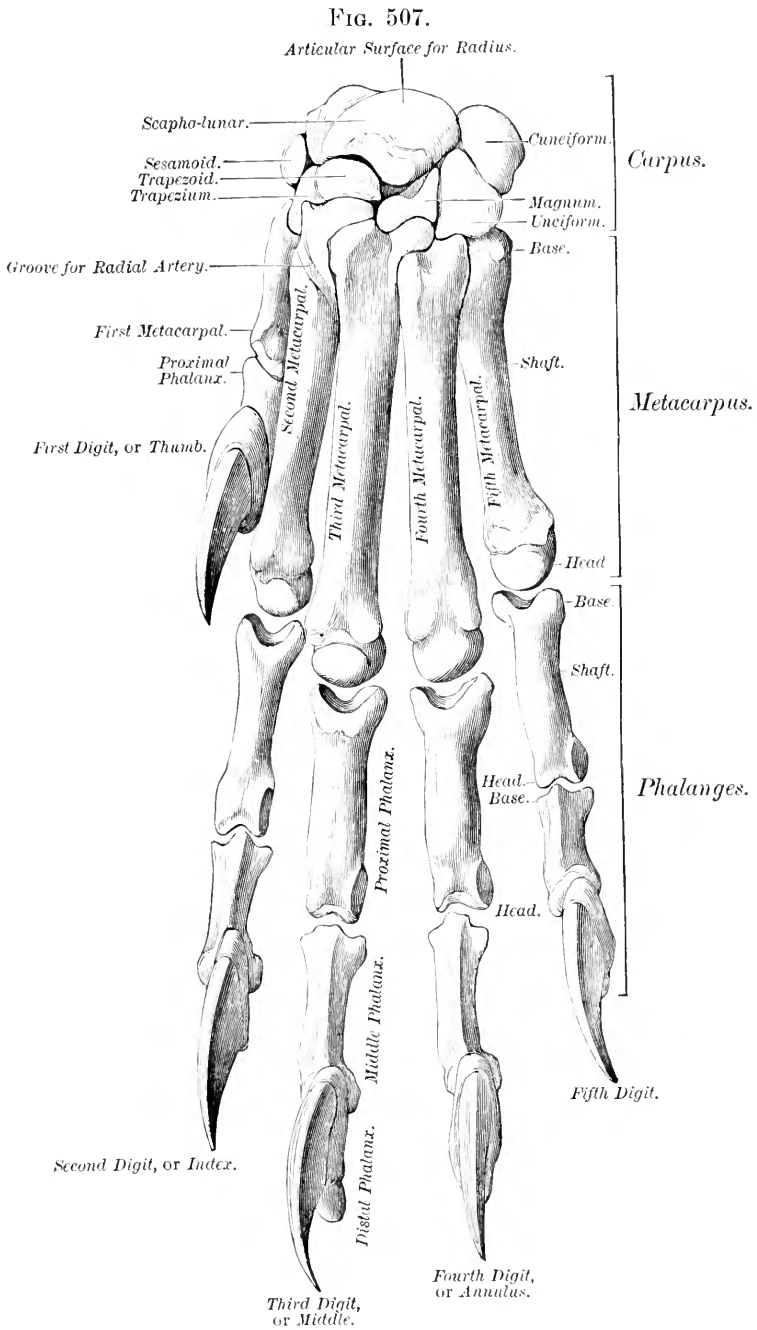
**Muscular Attachments.**—The fifth metacarpal affords attachment at the ulnar side of the base to the *extensor carpi ulnaris*, and on the palmar aspect to the *fourth palmar interosseous*, known as the *flexor brevis minimi digiti*, and the *opponens minimi digiti*.

**Ossification.**—The fifth metacarpal is developed from two centres of ossification, one for the shaft and one for the head.

### THE PHALANGES.

**General Description.**—The fourteen bones of the fingers or toes are called the phalanges. Three belong to every digit, or finger, except the thumb, which has but two. In every digit the phalanges are placed end to end, the proximal phalanx articulating by its proximal end with the head of the appropriate metacarpal, and by its distal end with the proximal end of the middle phalanx, which in turn articulates by its distal end with the terminal or distal phalanx.

The phalanges lie in the long axes and form most of the substance of the fingers. They are surrounded by tendons, blood-vessels, nerves, and the skin, but are practically free from muscles. The phalanges may be divided into three rows, the first including all the proximal, the second all the middle, and the third all the distal phalanges. The phalanges of any one row so closely resemble one another that they can be distinguished only by slight differences in size and curvature. The proximal phalanx of the thumb presents peculiarities of its own.



LEFT HAND, DORSAL ASPECT.

## PROXIMAL PHALANGES.

## CHARACTERS COMMON TO ALL.

The length of every proximal phalanx is a little more than four times greater than the average width; the thickness is less than the width. Compared with the metacarpal it appears stout, as the width is about the same as that of the metacarpal, while the length is only one-half.

It has a proximal end or base, a shaft, and a distal end or head.

The **Base** (Fig. 507) has transverse and antero-posterior diameters slightly greater than those of the shaft.

The **proximal surface** has a deeply emarginate palmar border, and is entirely occupied by a concave surface which articulates with the convex head of the metacarpal. The shape of this concavity is crescentic, the arcuate border being dorsal. It faces proximally and dorsally.

The **palmar surface** is slightly concave in both directions, and is continuous with the surface of the shaft. Its proximal border is incised. The lateral borders are prominent at the proximal end where they afford attachment for the sesamoid bones; distally they slope toward the long axis of the shaft.

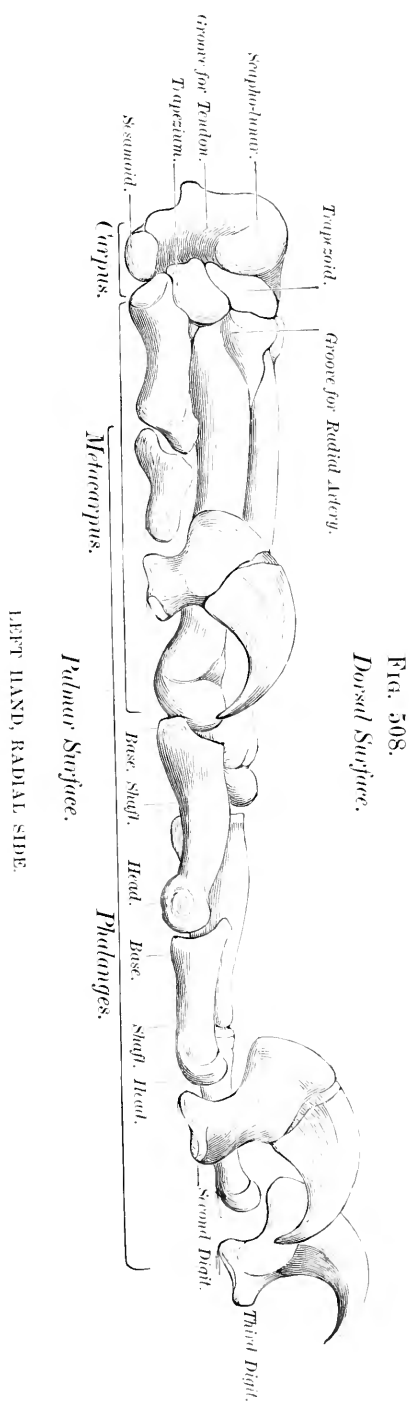
The **sides** of the base are gently convex, and marked by the insertion of interosseous muscles and ligaments. They slope dorsally and distally into the dorsal surface of the shaft.

The **dorsal surface** is convex transversely and continuous with the surface of the shaft.

The **Shaft** is slightly arched from the proximal to the distal end. The **lateral borders** are almost straight, and lie near the palmar aspect of the bone; they separate the dorsal and palmar surfaces. For most of their extent they are rounded, but at the distal end they present an inconspicuous rough area for ligamentous attachment.

The **dorsal surface** is convex in both directions; the palmar surface is flat transversely and concave from base to head.

The **Head** of the proximal phalanx is a cylinder placed transversely and deeply grooved in the middle line to form a pulley-like articular prominence or trochlea, which fits into the articular concavity in the base of the middle phalanx. The trochlea is entirely visible on the palmar aspect where it rises above the plane of the palmar surface of the shaft. A small portion only of the articular surface is seen



on the dorsal aspect of the bone. The **sides** of the head are circular and impressed by a pit for the attachment of ligaments.

#### PECULIARITIES OF THE PROXIMAL PHALANGES.

The proximal phalanx of the third digit is the largest; the others decrease in size in the following order: the fourth, the fifth, and the first or proximal phalanx of the thumb. The third and fourth have the same shape, the second and fifth are bent slightly toward the median line, and the median end of the trochlea is prolonged.

The proximal phalanx of the **thumb** is very short, and the articular surface on the base is shallow; the shaft is twisted about its long axis, the head facing more to the dorsal side than does the base, thus correcting the radio-dorsal position which the metacarpal sustains to the rest of the metacarpus and permitting the terminal phalanx to move in a dorso-palmar plane almost parallel with the planes of action of the phalanges of the other digits. As there is no middle phalanx to the thumb, the head articulates with the distal phalanx. The articular surface of the head is transversely cylindrical, and lacks the dorso-palmar groove which forms a trochlea on the proximal phalanges of the other digits.

#### MIDDLE PHALANGES.

##### CHARACTERS COMMON TO ALL.

Every middle phalanx is narrower and almost a fourth shorter than the corresponding proximal phalanx. It presents a proximal extremity or base, a shaft, and a distal extremity or head.

The **Base** is prismatic; narrow dorsally and expanded laterally and toward the palmar aspect. It has four surfaces, the proximal, the palmar, the radial, and the ulnar.

The **proximal surface** of the base has the outline of an equilateral triangle, one angle dorsal and the opposite side palmar. The palmar margin is emarginate, and the lateral margins are arcuate. Of the angles the dorsal is distinct and prolonged and the lateral are flat and slightly rounded. A well-marked median ridge runs from the dorsal angle to the palmar side. It is convex transversely and concave in the dorso-palmar direction to fit into the groove in the trochlea of the head of the proximal phalanx. The surface on each side of this ridge is concave in both directions, and is applied to the convex lateral part of the trochlea of the proximal phalanx.

The **palmar surface** is widened proximally and narrowed distally. Its proximal angles and lateral borders are rounded and prominent; they serve for ligamentous attachment. The greater part of the surface is occupied by a deep triangular median depression in which the tendon of the flexor sublimis digitorum muscle is inserted. Distal to this depression the surface is continuous with the palmar surface of the shaft.

The **radial and ulnar surfaces** slope from the edges of the palmar surface dorsally to the dorsal border, and face dorsally and to the radial and ulnar sides respectively; they are convex, and afford attachment to the ligaments of the joint.

The **dorsal border** is straight and rounded. It begins on the proximal dorsal angle, and is continuous with the dorsal border of the shaft. To the angle is attached the tendon common to the different extensor muscles.

The **Shaft** differs from the shaft of the proximal phalanx in being compressed from side to side. It is straight for most of its extent, but turns to the ulnar side at its distal end. It has three surfaces, the palmar, the radial, and the ulnar, separated by three borders, the dorsal, the radial, and the ulnar.

The **radial and ulnar borders** are placed on the palmar aspect of the bone, and are nearly parallel. For their proximal half they are emarginate; for their distal half the ulnar remains emarginate, but the radial border becomes arcuate.

The **dorsal border** turns to the ulnar side at the distal end.

The **palmar surface**, included between the radial and ulnar borders, is flat from the proximal to the distal end and flat or gently convex transversely.

The **radial and ulnar surfaces** slope from the radial and ulnar borders respectively, dorsally, as well as to the ulnar and radial sides respectively. The radial surface is sinuate in the proximo-distal direction and convex from the dorsal to the palmar side. The ulnar surface is flattened or gently convex from the dorsal to the ulnar border and deeply concave from the proximal to the distal end. This concavity receives the distal phalanx when retracted.

The **Head** is a half-cylinder placed obliquely to the long axis of the bone, in such manner that the ulnar end projects distally and beyond the ulnar surface of the shaft, producing an appearance of

the head having been turned to the ulnar side. It bears a smooth articular surface, which is nearly straight transversely, except at the palmar side, where it is slightly concave, and strongly convex from the dorsal to the palmar side; the ends are flattened, or depressed, and roughened for the attachment of ligaments. The head forms a hinge-joint with the concavity on the base of the distal phalanx.

#### PECULIARITIES OF THE MIDDLE PHALANGES.

Albeit all the middle phalanges are similar, the third and fourth, nevertheless, are of nearly equal length and about a fifth longer than the second and fifth, which are also nearly equal. The relation of the length to the width also varies, the median two being longer and more slender, the lateral two shorter and stouter. There is no middle phalanx to the first digit, or thumb.

#### DISTAL PHALANGES.

The Distal Phalanges (Fig. 508) are very different from the others. They are strongly compressed from side to side, high from the dorsal to the palmar border, and very short from the proximal to the distal end. On the distal surface is a thin curved vertical plate which supports the horny claw. The proximal end is the base; the central portion is the shaft, although it has lost the elongated form common to the shafts of long bones; the curved plate is the head. The phalanx has four surfaces.

The **proximal surface** is a narrow strip with a wide palmar side and ending in a rounded dorsal point above. It is deeply concave in the dorso-palmar direction, and almost flat from side to side. The palmar two-thirds are occupied by a shallow articular cavity for the head of the middle phalanx; the dorsal rounded third serves for the attachment of strong ligaments.

Of the margins of the **radial and ulnar surfaces**, the proximal is emarginate, the dorsal and distal are arcuate, and the palmar is straight. In the proximo-distal direction the surfaces are wide at the dorsal and narrow at the palmar border. They are gently convex, and extended distally and dorsally to form a hood, between which and the claw-plate is inserted the base of the claw. The palmar border is a small, rough, depressed quadrate or oval area, to which is fastened the tendon of the flexor profundus digitorum muscle. The dorsal border is much longer, and is convex in both directions.



The palmar third of the **distal surface** is little more than a rounded, straight border; above this there projects from the centre the bony claw-plate, surrounded by a deep cleft. When the lateral surfaces of the bone are broken away, this cleft is seen to extend back to the edges of the proximal surface. The claw-plate is thus seen to be the real shaft of the bone, the lateral surfaces being the extended surfaces of a projecting hood, or collar.

The **claw-plate** itself has the shape of a thin, curved triangle, the apex whereof points distally, and, when the phalanx is held with its proximal surface vertical, points also downward. In the position of rest, the distal phalanx is retracted against the ulnar side of the middle phalanx. The proximal surface then faces proximally, and is the palmar aspect; owing to the obliquity of the head of the middle phalanx, the ulnar surface of the distal phalanx faces in a distal direction as well as to the ulnar side.

The terminal phalanges of the several digits present no important points of difference.

The claw is a thin, curved, triangular, horny case which fits closely to the claw-plate; the latter, however, does not extend into the tip of the case. When the distal phalanx is retracted, the point of the claw is proximal to the palmar end of the proximal surface, and therefore no longer forms the end of the finger, and is useless.

**Determination.**—The **proximal phalanges** can be distinguished from the other phalanges by their size, their deeply concave bases, and their pulley-like distal ends. They can be distinguished from one another by their relative size and by the greater or less curvature toward the median line. Inasmuch as this curvature is directed toward the median line, when a proximal phalanx is held with the proximal end upward and the dorsal arched surface toward the student, the concavity of the curvature will be on the side to which the bone belongs if it be a fifth phalanx, and on the side opposite to that to which the bone belongs if it be a second phalanx. The proximal phalanx of the thumb is distinguished by its non-trochlear head. When the proximal surface is held uppermost, the head transverse and the dorsal surface toward the student, the articular surface on the base points to the side to which the bone belongs.

The **middle phalanges** can be distinguished by the prominence on the dorsal end of the base and by the lateral position of the head.

They are distinguished from one another by the differences in size; they decrease in the following order: the fourth, the third, the fifth, and the second. When the base is held toward the student, with the dorsal border uppermost, the concave side of the shaft is on the side to which the bone belongs.

The **distal phalanges** are known by their compressed shape and by the presence of the claw or claw support. When the proximal articular surface is held toward the student and the small palmar surface downward, a slight emargination at the lower part of the side of the articular surface is on the side to which the bone belongs.

**Ossification.**—The phalanges are developed from two centres, one for the base and one for the shaft.

**Muscular Attachments.**—**Proximal Phalanges.**—To the sides of the base of the proximal phalanges, and to the sesamoid bones, are attached the **palmar interosseous muscles**, that of the thumb being known as the **flexor brevis pollicis** and that of the little finger as the **flexor brevis minimi digiti**. The **lumbrical muscles** are attached by fascia to the radial side of the shafts of the four fingers. In addition insertion is given—

(1) By the phalanx of the thumb to the **adductor pollicis**, the **abductor pollicis**, and the tendon of the **extensor indicis**, known as the **extensor internodii pollicis**.

(2) By the proximal phalanx of the second or index finger, on the radial side of the base to the **first dorsal interosseous**, and on the ulnar side to the **adductor indicis**.

(3) By the proximal phalanx of the middle finger, on the radial side of the base to the **third dorsal interosseous**, and on the ulnar side to the **fourth dorsal interosseous**.

(4) By the proximal phalanx of the fourth finger, on the ulnar side of the base to the **fourth dorsal interosseous**.

(5) By the proximal phalanx of the little finger, at the base, on the radial side to the **adductor minimi digiti**, and on the ulnar side to the **abductor minimi digiti**.

**Middle Phalanges.**—A tendon of the **flexor sublimis digitorum** is inserted on the palmar side of the base of the middle phalanx; the general **extensor tendon**, including slips from the **lumbrical** and **interosseous muscles**, ends in the fascia on the dorsal aspect.

**Distal Phalanges.**—On the palmar side is inserted the tendon of

the *flexor profundus digitorum*; on the dorsal side are attached the retractor ligaments.

**Nomenclature.**—Phalanx is a Greek word meaning a line of soldiers in battle order. It was used by Aristotle because of the arrangement of the elements of each finger in a row. Strictly speaking, the whole digit would be a phalanx, but the word became restricted to each element of the finger. The actual joints of the fingers have been known as *nodi*, or knobs, and the short bones which form the joints, the phalanges, have been called *internodia*, as we see in the name of the muscle *extensor primi internodii pollicis*, the extensor of the first phalanx of the thumb.

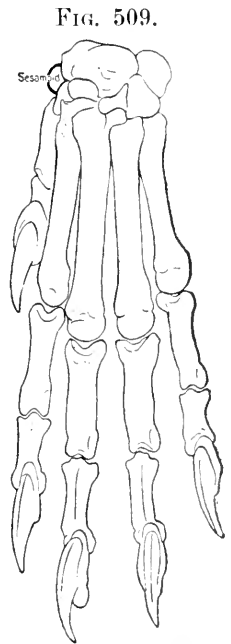
### SESAMOID BONES OF THE HAND.

The hand possesses, in addition to the twenty-six bones already described, eleven small ossicles which are developed in tendons. One of these is found in the tendon of the abductor pollicis muscle, closely applied to the radial end of the scapho-lunar. It is a very small bone, with a circular outline, a convex outer surface, and a smooth inner surface, which is covered with cartilage and applied to the facet on the dorsal side of the process of the scapho-lunar.

The remaining ten sesamoids are in five pairs, a pair on the palmar side of the metacarpophalangeal joint of every digit, where they furnish protection to the joint and serve for the attachment of muscles and ligaments.

Every one of these sesamoids has the shape of a cocked hat, presenting a dorsal, a medial, and a lateral surface.

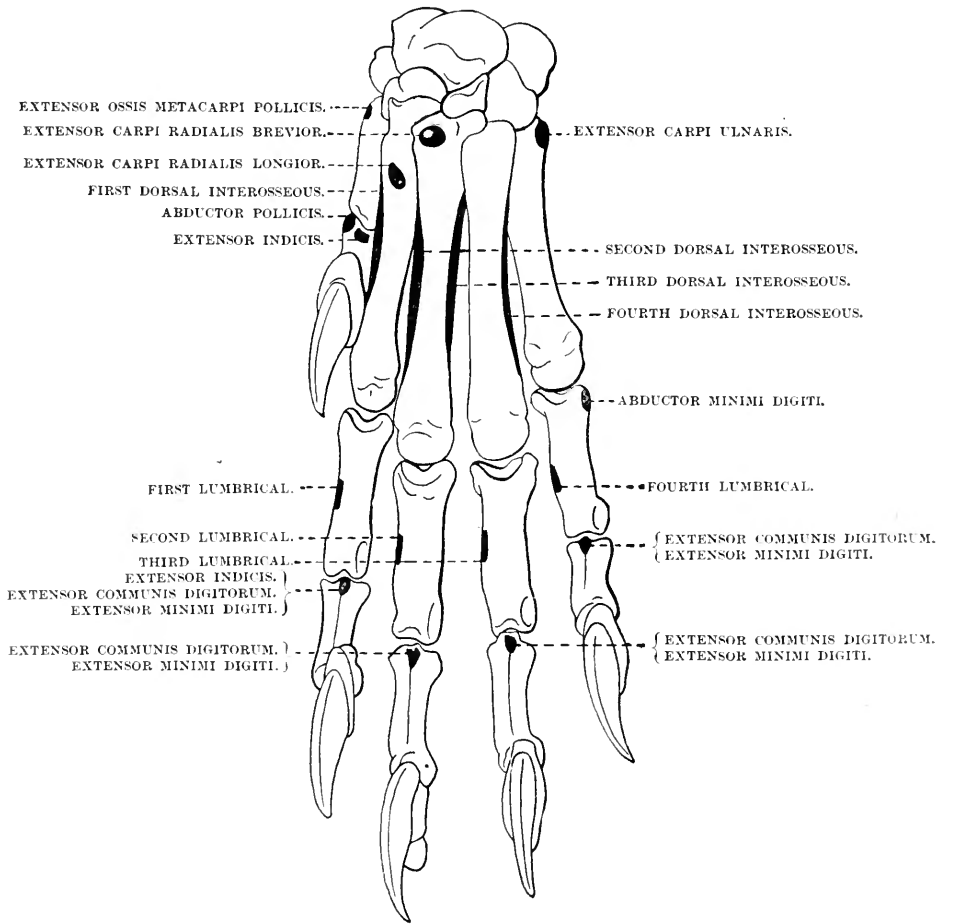
The **dorsal surface** is narrow, and pointed at the proximal end. Its lateral outline is arcuate; the medial outline is almost straight. The surface is concave from the distal to the proximal end, and convex from side to side. It does not face directly to the dorsal side of the hand, but dorsally and to the middle line of the finger. It encroaches, therefore, upon the medial surface. The dorsal surface glides upon half of the head of the metacarpal, and is separated from its fellow at the longitudinal crest.



POSITION OF SESAMOID.

The lateral and medial surfaces are triangular; the base of the triangle is the dorsal border, and the apex is at the proximal ventral end. The lateral surface is gently convex. The medial surface is smaller than the lateral surface, and somewhat excavated for the attachment of the transverse ligaments. A small, triangular, flattened surface at the disto-lateral angle affords attachment to ligaments which bind the bone to the palmar end of the base of the phalanx.

FIG. 510.



MUSCLES ATTACHED TO THE HAND. DORSAL ASPECT.

MUSCULAR ATTACHMENTS ON THE HAND.

MUSCLES ATTACHED TO THE CARPUS.

On the Pisiform, the insertion of the **flexor carpi ulnaris**, the origin of the **abductor minimi digiti**.  
On the Trapezium and Trapezoid, the origin of the **flexor brevis pollicis**.  
On the Magnum, part of the origin of the **adductor pollicis**.

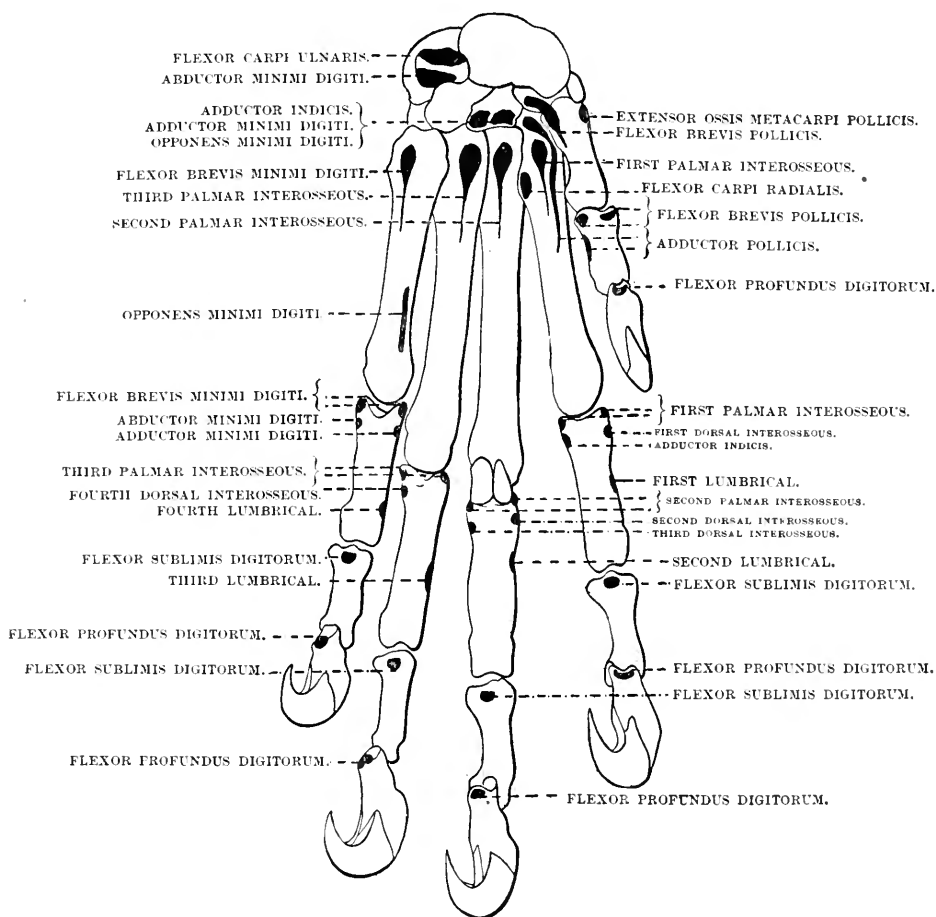
MUSCLES ATTACHED TO THE METACARPUS AND PHALANXES.

On the First Metacarpal, the insertion of the **extensor ossis metacarpi pollicis**, and part of the origins of the **first dorsal interosseous** and the **flexor brevis pollicis**.

On the First Digit:

- (a) Proximal phalanx, the insertion of the **abductor pollicis**, the **flexor brevis pollicis**, the **adductor pollicis**, and the **extensor internodii pollicis** (a slip of the **extensor indicis**).
- (b) Distal phalanx, the insertion of the **flexor profundus digitorum**.

FIG. 511.



MUSCLES ATTACHED TO THE HAND. PALMAR ASPECT.

On the Second Metacarpal, the insertion of the **extensor carpi radialis longior** and the **flexor carpi radialis**, the origin of the **adductor pollicis**, and the **first palmar and dorsal interossei**.

On the Second Digit :

- (a) Proximal phalanx, the insertion of the palmar interosseous and (radial side) the dorsal interosseous and (ulnar side) the adductor indicis.
- (b) Middle phalanx, the insertion of the flexor sublimis digitorum, the palmaris longus, the extensor indicis, the extensor communis digitorum, the extensor minimi digiti, and the first lumbrical.
- (c) Distal phalanx, the flexor profundus digitorum.

On the Third Metacarpal, the insertion of the extensor carpi radialis brevis, the origin of the second palmar interosseous, and the second and third dorsal interosseous.

On the Third Digit :

- (a) Proximal phalanx, the insertion of the second palmar interosseous, the second and third dorsal interosseous, and the second lumbrical.
- (b) Middle phalanx, the insertion of the flexor sublimis digitorum, the palmaris longus, the extensor communis digitorum, and the extensor minimi digiti.
- (c) Distal phalanx, the insertion of the flexor profundus digitorum.

On the Fourth Metacarpal, the origin of the third palmar interosseous and the fourth dorsal interosseous.

On the Fourth Digit :

- (a) Proximal phalanx, the insertion of the third palmar and the fourth dorsal interosseous and the third lumbrical.
- (b) Middle phalanx, the insertion of the flexor sublimis digitorum, the palmaris longus, the extensor communis digitorum, and the extensor minimi digiti.
- (c) Distal phalanx, the insertion of the flexor profundus digitorum.

On the Fifth Metacarpal, the insertion of the extensor carpi ulnaris and the opponens minimi digiti; the origin of the flexor brevis minimi digiti.

On the Fifth Digit :

- (a) Proximal phalanx, the insertion of the adductor minimi digiti, the abductor minimi digiti, the flexor minimi digiti, and the fourth lumbrical.

- (b) Middle phalanx, the insertion of the *palmaris longus* and the *flexor sublimis digitorum*, the *extensor communis digitorum*, and the *extensor minimi digiti*.
- (c) Distal phalanx, the insertion of the *flexor profundus digitorum*.

VARIATIONS IN THE HAND.

An important abnormality of the hand is produced by an increase in the number of the fingers. This condition, which is known as **polydactylism**, is not uncommon in the cat, and instances have been reported in which it has run through families for several generations.<sup>1</sup>

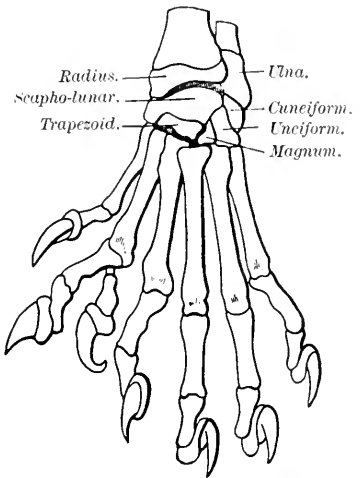
The additional fingers are always added to the radial, or thumb, side of the hand, and the index, middle, ring, and little fingers always remain normal. The additional fingers may be perfectly developed, or be in part rudimentary; they may be free or joined together. The terminal phalanx of an additional finger either may be retracted into an excavation on the radial side of the middle phalanx, when the digit is said “to be formed like a digit of the opposite hand,” or, inasmuch as the middle phalanx is not excavated on either side, cannot be retracted at all; in this case the digit is termed “indifferent.”

Both hands are usually simultaneously abnormal, in the same manner but not necessarily to the same extent; when the hands are abnormal the feet also may be abnormal.

According to Bateson,<sup>2</sup> the known examples of polydactylism in the hand of the cat may be grouped in three classes:

1. The hand has five digits, the normal number, but the thumb has three phalanges and is formed like a digit of the opposite hand.
2. The hand has six digits, all with three phalanges. The first digit is indifferent, the second is formed like a digit of the opposite

FIG. 511A.



LEFT HAND WITH SUPERNUMERARY DIGITS.

<sup>1</sup> Poulton, *Nature*, 1883, p. 20; 1887, p. 38.

<sup>2</sup> *Materials for the Study of Variation*, pp. 313-324.

hand; the remaining four digits, as usual, are normal. I have collected several examples of this type of variation.

3. The hand has seven digits, whereof the first is always indifferent, and either rudimentary or with two or three phalanges. The second and third digits are usually more or less united; the second is always formed like a digit of the opposite hand; the third is always indifferent, and varies in development from a small nail to a complete digit with its own metacarpal. The remaining four digits are normal (Fig. 511A).

In polydactylous hands the carpal bones are often abnormal; the scapho-lunar is always very wide, and may be united with the trapezium; the trapezoid may be greatly enlarged, or there may be two trapezoids and a separate trapezium.

#### HUMAN HAND.

The human **Carpus** has one more bone than the carpus of the cat; the scaphoid and the semilunar are not united. The pisiform is a rounded and relatively small bone; the trapezoid resembles in shape the trapezium of the cat; the magnum is larger and more regular, and the unciform exhibits a strong palmar hook.

The **scaphoid** (Fig. 512, 1) articulates by an oval proximal convexity (*b*) with the radius, by a distal concavity (*c*) with the magnum, by a crescentic facet on the ulnar margin (*d*) with the semilunar, and by a triangular area at the radial end of the dorsal surface (*e*) with the trapezium and the trapezoid. It presents on the dorsal surface (Fig. 513) a transverse ridge for ligaments, and at the radial palmar end a well-marked tubercle.

The **semilunar** (Fig. 512, 2) is obliquely crescent-shaped; the concave surface is distal (*b*) and articulates with the magnum, except along a small ulnar strip (*c*) which joins the unciform. The ulnar surface is flattened and exhibits an oval area (*d*) for articulation with the cuneiform. The convex proximal surface (*a*) moves upon the radius. The crescentic radial surface articulates with the scaphoid.

The **cuneiform** (Fig. 512, 3) is pyramidal. Its radial surface (*b*) articulates with the semilunar. Its distal surface is occupied by a large undulating facet (*c*) for the unciform. The ulnar half of the palmar surface bears a circular, slightly convex facet (*d*) for the pisiform.

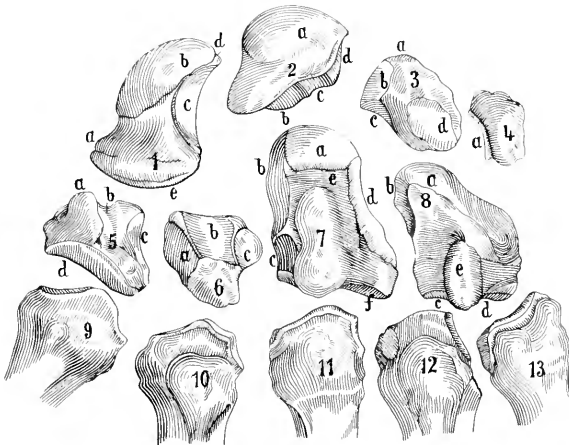
The **pisiform** (Fig. 512, 4) is an oval bone, the long axis of which



is directed downward and to the radial side. It has a slightly concave dorsal articular surface (*a*) for the cuneiform. To the rounded aspect are attached the abductor minimi digiti and flexor carpi ulnaris muscles. The pisiform does not articulate with the ulna.

The **trapezium** (Fig. 512, 5) is not so strongly crescentic as in the cat, and the palmar surface (5) is larger. It articulates by a concave proximo-ulnar facet with the scaphoid, by a larger concave ulnar surface (*c*) with the trapezoid, by a saddle-shaped radio-distal surface (*d*) with the first metacarpal, and by a small ulno-distal facet

FIG. 512.



PALMAR ASPECT OF THE CARPAL BONES AND THE BASES OF THE METACARPALS.

1, scaphoid: *a*, tuberosity; *b*, with radius; *c*, with magnum; *d*, with semilunar; *e*, with trapezium and trapezoid. 2, semilunar: *a*, with radius; *b*, with magnum; *c*, with unciform; *d*, with cuneiform. 3, cuneiform: *a*, with interarticular cartilage; *b*, with semilunar; *c*, with unciform; *d*, with pisiform. 4, pisiform: *a*, with cuneiform. 5, trapezium: *a*, ridge; *b*, groove for the flexor carpi radialis muscle; *c*, with trapezoid and second metacarpal; *d*, with first metacarpal. 6, trapezoid: *a*, with trapezium; *b*, with scaphoid; *c*, with magnum. 7, magnum: *a*, with semilunar; *b*, with scaphoid; *c*, with trapezoid and second metacarpal; *d*, with unciform; *e*, for ligaments; *f*, with third and fourth metacarpals. 8, unciform: *a*, with cuneiform; *b*, with semilunar; *c*, with fourth metacarpal; *d*, with fifth metacarpal; *e*, hook. 9, 10, 11, 12, and 13, first, second, third, fourth, and fifth metacarpals.

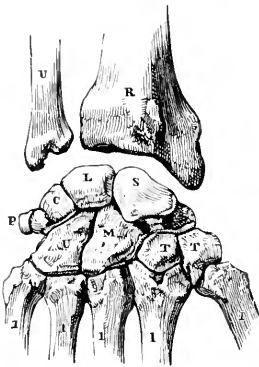
with the second metacarpal. Its palmar surface is marked by a deep groove (*b*) for the tendon of the flexor carpi radialis muscle and a radial ridge (*a*) for the flexor brevis, opponens, and abductor pollicis muscles. The opponens pollicis is attached also to the rough radial aspect.

The **trapezoid** (Fig. 512, 6) is crescent-shaped; the sharp edge of the crescent forms an ulno-distal border; above this border is a concave ulnar facet (*c*) for the magnum, and below it is a saddle-shaped distal facet for the second metacarpal. The small proximal surface (*b*) articulates with the scaphoid, and the larger radial surface (*a*) with the trapezium.

The **magnum** (Fig. 512, 7) in man is the largest bone of the wrist. It is not irregular, as in the cat, and the proximal part, the head (*a*, *b*), is rounded, transversely oval, and articulates with the scaphoid and the semilunar. The quadrate body articulates by its ulnar surface (*d*) with the unciform, by its radial surface (*c*) with the trapezoid, and by three facets on its distal surface (*f*) with the second, third, and fourth metacarpals.

The **unciform** (Fig. 512, 8) is wedge-shaped, with the apex (*b*), which articulates with the semilunar, at the proximal and radial sides.

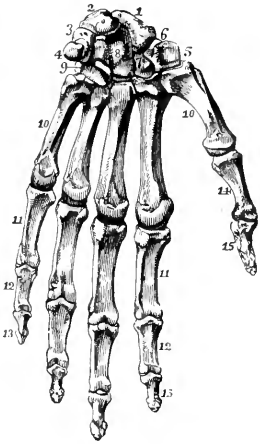
FIG. 513.



BONES OF THE CARPUS, AND THOSE WITH WHICH THEY ARTICULATE. RIGHT HAND. POSTERIOR VIEW.

Of the upper bones, U is the lower end of the ulna, and R is the lower end of the radius. Of the bones of the carpus, in the first row, S is the scaphoid, L the lunate, C the cuneiform, and P the pisiform bone; and in the second row, T T are the trapezium and trapezoid, M the magnum, and U the unciform bones. 1, the metacarpal bones.

FIG. 514.



LEFT HAND, VIEWED IN FRONT, OR ON THE PALMAR SURFACE.

1, scaphoid bone; 2, semilunar; 3, cuneiform; 4, pisiform; 5, trapezium; 6, groove in the latter; 7, trapezoid; 8, magnum; 9, unciform; 10, the five metacarpal bones; 11, proximal row of phalanges of the fingers; 12, middle row; 13, distal row; 14, 15, phalanges of the thumb.

The distal base (*e*, *d*) articulates with the fourth and fifth metacarpals, the flattened radial side with the magnum, and the sloping, undulating ulno-proximal side (*a*) with the cuneiform. The palmar surface gives off at its ulno-distal angle the unciform process (*e*) for the attachment of the opponens and flexor minimi digiti muscles.

The **Metacarpus** (Fig. 514) has five well-developed metacarpals; that of the thumb is much longer than the corresponding metacarpal of the cat. The proximal surfaces of the metacarpals are not so irregular, and are more nearly upon one level. The shafts are shorter and more distinctly prismatic; the distal extremity lacks the crest on the articular surface.

The **Digits** (Fig. 514) have the same number of phalanges as in the cat,—namely, three for every finger except the thumb, which has but two. The middle digit is the longest, the ring finger the next in size, the second the next, the little finger the next, and the thumb the shortest.

The **proximal phalanges** resemble those of the cat, but the articular surfaces on the ends are less deeply concave transversely.

The **middle phalanges** are like the proximal, but are shorter and flatter, and the proximal articular surface is transversely biconcave.

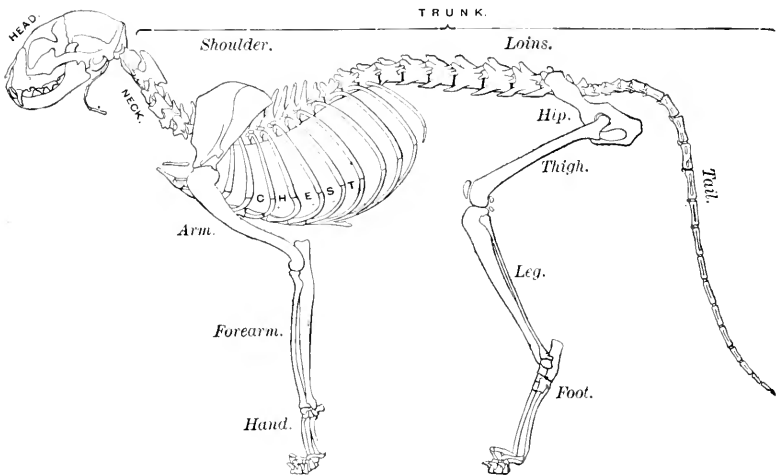
The **terminal or ungual phalanges** are small, flat, tongue-shaped bones, with transversely biconcave proximal surfaces and roughened arcuate distal borders.

The human hand is relatively shorter and broader than the hand of the cat. If the arm be allowed to hang vertically and the humerus be held immovable, the hand can still be turned to the supine position with the palm forward, or to the prone position with the palm backward; this is due to the extensive rotation of the lower end of the radius about the lower end of the ulna. The cat walks on the digits, with the palm of the hand facing backward and the humerus directed from above downward and outward. If the humerus be fixed in this position, the palm of the hand can be brought only to a partial supination, so as to face inward.

## CHAPTER IX

### THE PELVIC LIMBS

FIG. 515.



THE REGIONS OF THE SKELETON.

EACH Posterior or Pelvic Limb comprises (Fig. 515) :

- (1) A proximal element, the **hip** or **haunch**, firmly attached to the trunk and scarcely distinguishable from it.
- (2) A more or less free element, the limb proper, which is divided into three serial parts, the **thigh**, the **leg**, and the **foot**. The foot is subdivided into a proximal part, the **tarsus**, a middle part, the **meta-tarsus**, and a distal part, the **digits** or **toes**.

The Hip is supported by the single irregular **innominate** or **hip bone** (Fig. 516), which joins the sacrum and its fellow of the opposite side to form a complete bony ring. Each half of this ring, therefore each innominate, is known as a **pelvic girdle**.

The Thigh is supported by one cylindrical bone, the **femur**.

The Leg contains two long bones, the **tibia** and the **fibula**, placed side by side. They are fixed in that position: the foot, therefore, cannot be turned in pronation and supination.

The Foot is supported by twenty-four bones, not including the eight small **sesamoid** bones.

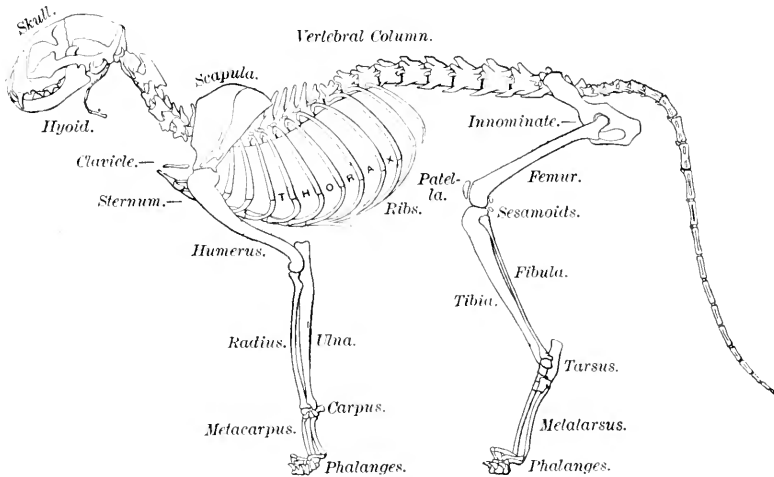
The Tarsus has seven tarsal bones : the astragalus, the calcaneum, the scaphoid, the entocuneiform, the mesocuneiform, the ectocuneiform, and the cuboid.

The Metatarsus has five metatarsal bones.

Inasmuch as the first digit or great toe is rudimentary in the cat, the distal part of the foot is supported by four series of phalanges, every series comprising three phalanges.

### THE INNOMINATE BONE.

FIG. 516.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

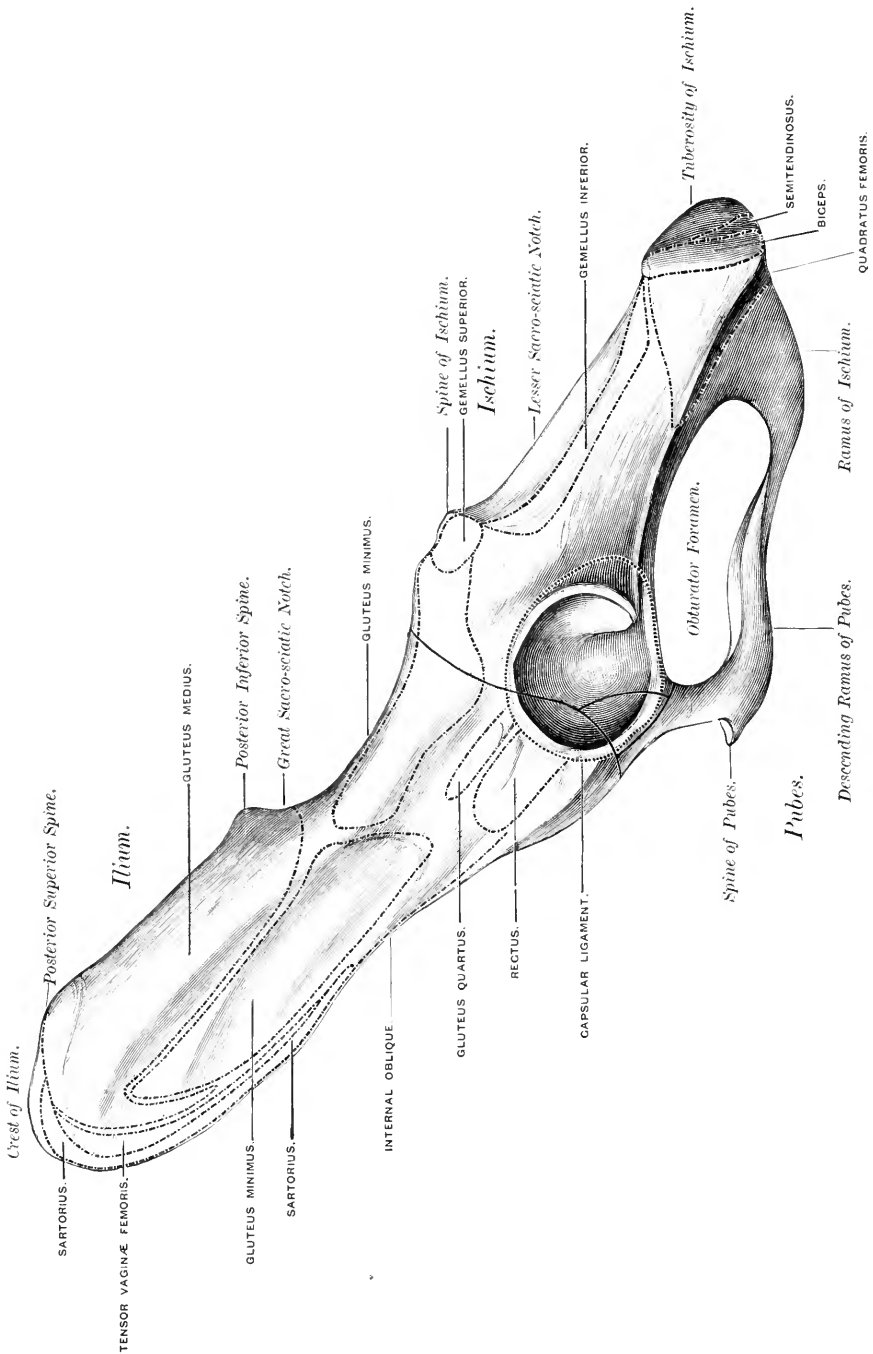
**General Description.**—The Innominate or Hip Bones form the ventral wall and the sides of the pelvis (Fig. 516). They are united below, but are separated above by the sacrum.

Each innominate bone is constituted of three elements, which are separate in early life but so coalesced in one mass in the adult that their boundaries are more or less artificial. A fourth bone, which lies at the junction of the other three and unites with one of them, is present in the cat, but is not always found in the innominates of mammals. The three bones which constitute the innominate are the ilium, the ischium, and the pubes. They are arranged around the cup-shaped articular cavity, or acetabulum,<sup>1</sup> which lies on the external surface (Fig. 517).

The ilium is the solid, elongated part which projects upward, forward, and outward, and articulates with the sacrum. Its lower

<sup>1</sup> A shallow vessel.

FIG. 517.



LEFT INNOMINATE BONE, OUTER ASPECT.

boundary is a line drawn nearly at right angles to its long diameter through the upper fifth of the acetabulum.

The ischium and pubes surround the oval opening or obturator<sup>1</sup> foramen on the lower part of the bone; they are L-shaped, and so arranged that the end of the horizontal branch of the one joins the end of the vertical branch of the other (Fig. 518).

The ischium is the stout L which lies dorsal to the obturator foramen. From in front it is directed downward, backward, and outward, then bends at a right angle and passes downward, inward, and forward to meet a branch of the pubes. It enters into the formation of about three-fifths of the acetabulum.

The pubes lies in front and on the median side of the obturator foramen. It does not really reach the acetabulum; the fourth element, the cotyloid<sup>2</sup> bone, excludes it. If we regard the cotyloid bone as an epiphysis of the pubes, we find that the pubes then forms about one-fifth of the acetabulum.

The Ilium is a flat, tongue-shaped bone. It is slightly narrower in the middle than at the upper free end, and still wider below where it joins the pubes and the ischium. The greatest breadth is contained two and one-fifth times in its length, and its average thickness is contained four times in the greatest width, and therefore about eleven times in the length. It presents an external and an internal surface, limited by anterior and posterior borders and by the upper border, called the crest.

The external surface (Fig. 517) has the length and breadth about equalling the length and breadth of the entire ilium. It is limited in front by the anterior border, which can be recognized as the one continued below to the pubes. It is limited behind by the posterior border, namely, the one which is more emarginate and is continued below on the ischium. The crest of the ilium limits the surface above, and an imaginary straight line drawn at right angles to the long axis through the upper fifth of the acetabulum separates it from the external surfaces of the ischium and pubes below. The anterior border begins above at the crest in a rounded angle, known as the anterior superior spine of the ilium, below which for about its upper third it is straight. It then bends backward, at a well-marked anterior inferior spine of the ilium, and, leaving the apparent edge of the bone, runs

<sup>1</sup> From *obturo*, to stop up.

<sup>2</sup> From *cotyle*, a cup, and *eides*, like.

straight down to the front of the top of the acetabulum. The upper margin has the curve of the crest, and is arcuate. When the bone is held with the long axis vertical the posterior end of the upper margin is lower than the anterior end. The posterior margin is, therefore, shorter than the anterior margin. It is the outer edge of the posterior border, and forms an obtuse angle with the superior margin at the **posterior superior spine** of the ilium. Its upper half is straight, and the lower half, below the **posterior inferior spine** of the ilium, is emarginate. The emargination is the **greater sacro-sciatic notch**.

The upper half of the external surface of the ilium is depressed or faintly concave in all directions. It is crossed obliquely by a line which begins above, near the anterior superior spine, and is continuous below the posterior inferior spine with the outer edge of the posterior border. This line marks approximately the boundary between the areas of origin of the gluteus medius muscle and the upper part of the gluteus minimus. A narrow strip along the front part of the crest, adjacent to the anterior border, gives origin to the tensor vaginae femoris muscle.

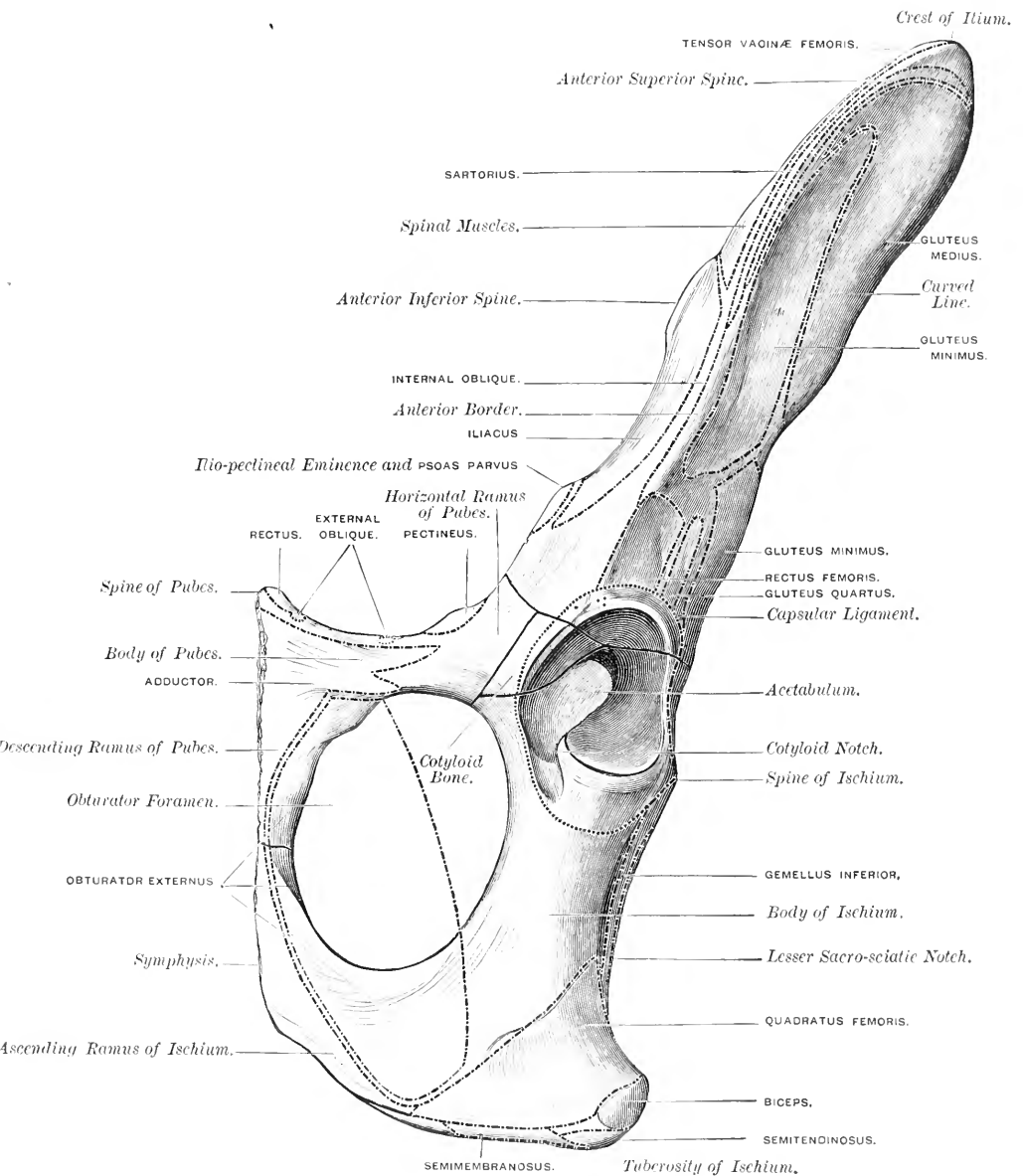
The lower half of the external surface is flat above, but becomes wider as it approaches the acetabulum, and presents an anterior part facing directly outward and a posterior part facing upward and backward. On the anterior larger part, above the acetabulum, is a roughened quadrate area from which spring the rectus femoris and gluteus quartus muscles. On the posterior part is a portion of the area of origin of the gluteus minimus.

The part of the ilium which enters into the formation of the acetabulum (Fig. 518) is a small, smooth excavation, with an arcuate upper border and a straight lower border; as it forms the top of the acetabulum, it faces downward, backward, and outward. To the anterior border is attached the aponeurosis of the internal oblique muscle.

It will be observed that a long, narrow, triangular area, which appears on the anterior side of the lower two-thirds of this external aspect of the bone, has not been included in the external surface. It is rather an anterior surface, since it lies to the inner, or median, side of the anterior border from the anterior inferior spine down to the acetabulum, and is limited within by a line called the **ilio-pectineal line**, which, beginning also at the anterior inferior spine, appears as



FIG. 518.



LEFT INNOMINATE BONE, INFERIOR OR VENTRAL ASPECT.

the true anterior margin of the bone, and is continued below transversely along the pubes. The ilio-pectineal line is gently emarginate, and presents above the level of the acetabulum a small more or less well-developed projection, known as the **ilio-pectineal eminence**. This small anterior surface faces outward and downward, and its upper half gives origin to part of the iliacus muscle; the ilio-pectineal eminence and the adjoining region receive the insertion of the *psoas parvus* muscle.

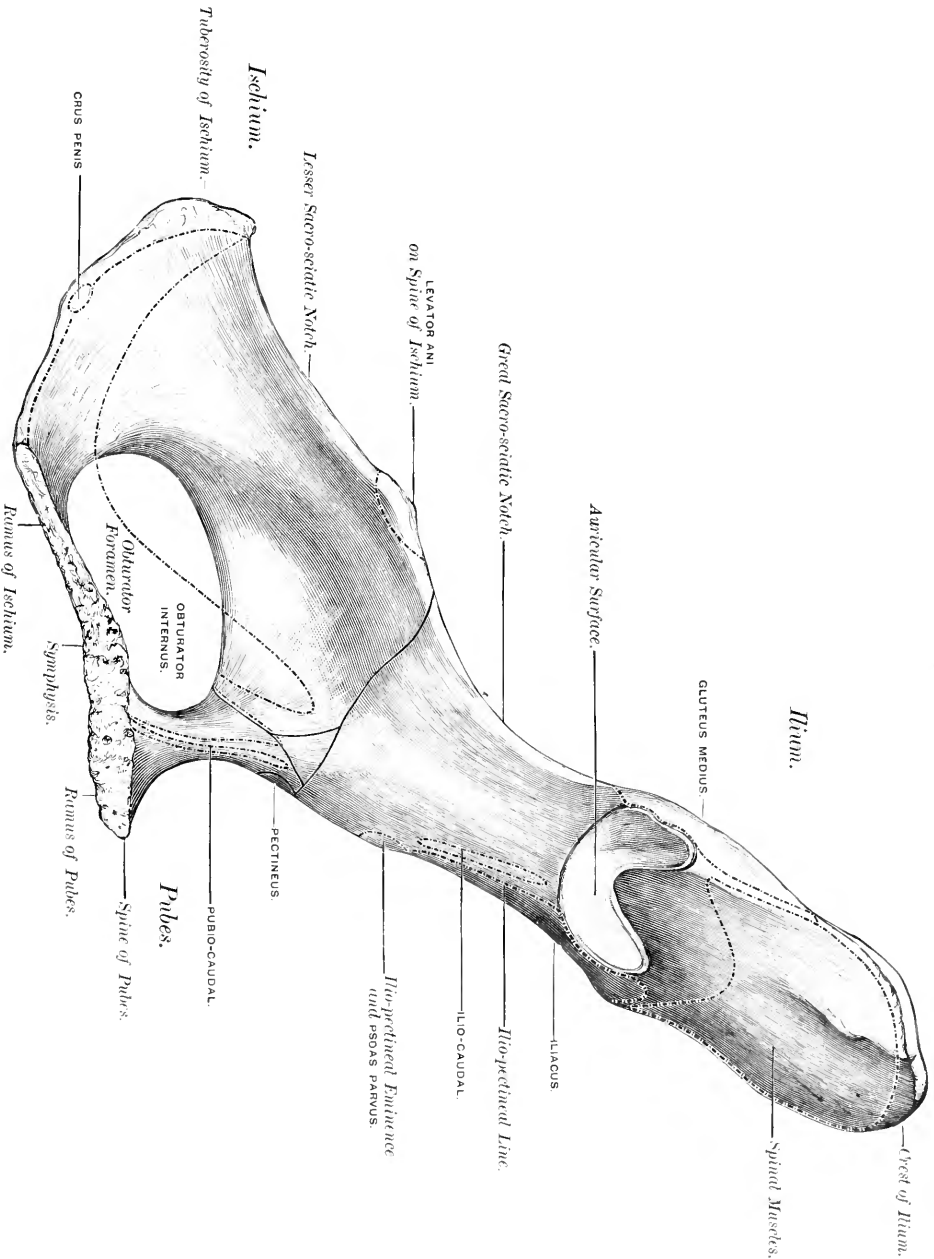
The **internal surface** of the ilium (Fig. 519) has approximately the same size and shape as the external surface. It presents two distinct portions: (1) an upper roughened portion, which comprises more than half of the entire surface and is involved directly and indirectly in the articulation with the vertebral column; and (2) a lower smooth portion, forming the anterior dorsal region of the lateral wall of the pelvic cavity.

(1) The upper portion is oblong, sometimes twice as long as wide. Its anterior and posterior margins are parallel; its upper margin is the arcuate crest of the ilium. The lower margin is also the lower arcuate margin of a flattened, crescentic elevation, called, from its resemblance to the human ear, the **auricular surface**, which articulates with a corresponding auricular surface on the lateral mass of the sacrum. Above the auricular surface is a roughened area where the sacro-iliac ligaments are attached. The smooth space which lies above this region and which slopes outward and forward to the crest gives origin to the lower end of the complex system of spinal muscles.

(2) The lower portion, rather less than half of the internal surface, is wider below than above. It is limited in front by the ilio-pectineal line, and behind by the emarginate posterior border. The emarginate upper margin is the sharp prominent lower edge of the auricular surface. The lower boundary is an imaginary transverse line about seven millimetres above the highest point of the obturator foramen. This part is flat or gently convex above, and faintly concave below, where it is continuous with the surfaces of the pubes and ischium. It faces directly toward the middle of the pelvic cavity, and gives attachment only to the iliacus muscle along the ilio-pectineal line, and to the ilio-caudal muscle by a narrow area of origin posterior to this line.

The **crest** of the ilium is the arched upper border of the bone,

FIG. 519.



LEFT INNOMINATE BONE, INNER ASPECT.

which can be plainly felt in the living animal. It runs obliquely to the long axis of the bone, but, owing to the oblique position of the innominate in the body, its anterior and posterior ends are on about the same level. The border is thin in front at the anterior superior spine, but widens toward its termination behind on the posterior superior spine. It is more or less rounded, and affords attachment to the sartorius muscle.

The **posterior border** of the ilium is broad and flattened above, but gradually becomes narrower and sharper, until at its lower end it is thin and prominent. In its upper two-fifths it is rough for the attachment of the gluteus medius muscle, and is prolonged inward on the dorsal surface of the auricular process at the posterior inferior spine. In its lower three-fifths it is smooth and concave from above downward, producing the great sacro-sciatic notch and giving attachment to the lower part of the gluteus minimus muscle. The posterior border faces upward and backward.

The **Ischium** forms the great part of the rest of the innominate. It may be recognized as the stout L-shaped bone which lies above, behind, and also partly below the obturator foramen; it is that most posterior part of the pelvis upon which the cat rests in sitting. It is divided into a dorsal stout portion, the body, and a ventral flattened bar, the ramus. The region about the swollen angle at the junction of the two parts is known as the **tuberosity** of the ischium.

The **body** is three times as long as wide, and prismatic on cross-section. It presents three surfaces, the external (ventral), the internal (dorsal), and the posterior (lateral), separated by three borders: the external, extending from the dorsal border of the acetabulum to the tuberosity; the posterior, or dorsal, continuous with the posterior border of the ilium; and the internal, bounding the obturator foramen.

The **external surface** (Fig. 518) is limited above and in front from the ilium by the imaginary line through the upper part of the acetabulum, dorsally by the posterior surface of the dorsal lip of the acetabulum and by the external border, and ventrally from the pubes by an imaginary oblique line in the acetabulum, and further back from the obturator foramen by the internal border. Behind the foramen, the surface is continuous behind and below with the outer surface of the ramus. The outer lip of the tuberosity, which is the posterior limit of the innominate, forms the posterior boundary of the external sur-

face of the ischium. The external surface is much longer than wide, and its most conspicuous feature is the acetabulum on the upper end, to the formation whereof the ischium contributes at least three-fifths. Below and behind the acetabulum the surface is slightly convex transversely and faintly concave from the anterior to the posterior end. It forms a smooth surface, over which the obturator externus muscle passes from within outward. Behind the middle point of the posterior border is the beginning of a line which crosses the surface obliquely, parallel to the edge of the obturator foramen, and is continued on the external surface of the ramus. This line is the anterior boundary of the triangular area of origin of the quadratus femoris muscle. The external surface faces downward, forward, and outward.

The **posterior surface** of the ischium (Fig. 517) is a narrow strip included between the posterior border on the dorsal side and the rim of the acetabulum and the external border on the ventral side. It is continuous above with the dorsal part of the external surface of the ilium, and ends below at the dorsal lip of the tuberosity. On the posterior border, at the junction of the upper with the middle third, is the projection known as the **spine** of the ischium, below which the surface is slightly narrowed by the rolling outward of the posterior border. The posterior surface is concave, and gives attachment to the following muscles: above, to the lower part of the gluteus minimus; around the spine, to the gemellus superior; and ventral to the posterior border, to the gemellus inferior. In the position in which the pelvis is placed for study the posterior surface faces outward and slightly upward.

The **internal surface** (Fig. 519) of the body of the ischium is as wide as the two other surfaces combined. It is limited above and in front from the inner surfaces of the ilium and pubes by imaginary lines only. On the ventral side, along the obturator foramen, is the inner border, whereof the continuation back to the tuberosity, parallel with the posterior dorsal border, is the artificial line of division from the inner surface of the ramus.

The internal surface does not lie in one plane; the anterior part faces inward, but the posterior part slopes upward and outward from a line drawn from the spine to the lowest part of the inner border; hence it faces upward, inward, and backward. The entire surface forms the lower part of the lateral wall of the pelvis. It is almost

free from muscular attachment, although covered by the obturator internus, which has its origin partly anterior and partly posterior to the obturator foramen.

The **posterior (dorsal) border** (Fig. 520) runs downward, backward, and outward. Its upper third is gently arcuate, sharp, and presents at the lower end the blunt, inconspicuous spine which gives attachment on the outer side to the gemellus superior, and on the inner side to the levator ani muscle. Below the spine the border is slightly emarginate and rolled to the outer side, producing a smooth surface, over which the internal obturator glides in order to join the external obturator and the gemelli muscles passing to the femur.

The **inner (ventral) border** faces inward, downward, and forward. It is emarginate and continuous with the border of the ramus of the ischium and the border of the pubes, and forms part of the edge of the obturator foramen.

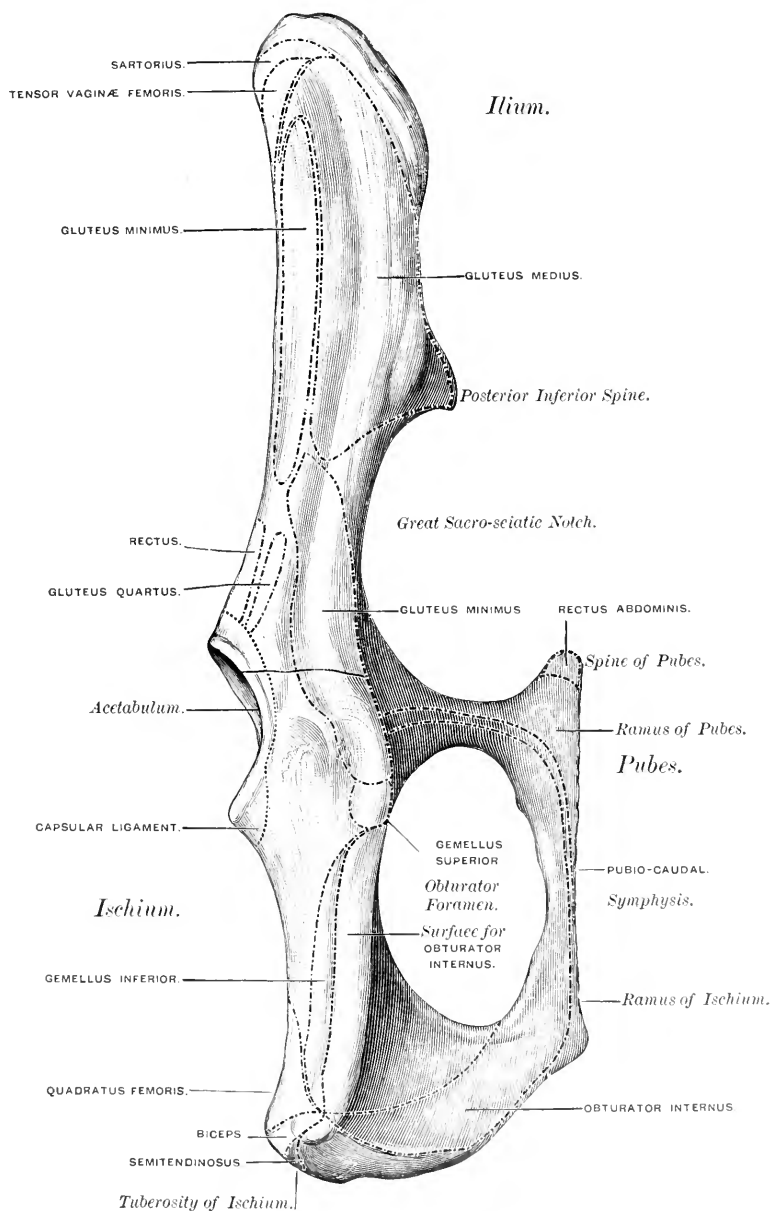
The **external border** (Fig. 520) faces downward, outward, and forward, and is directed from the acetabulum downward, backward, and slightly outward. It is often obscure above, but is more distinct at its lower end, which joins the tuberosity. It forms the external margin of the area of origin of the gemellus inferior muscle.

The **ramus, or ascending ramus**, of the ischium is a thin, hook-shaped, bony plate which is given off from the inner side of the lower part of the body of the bone at right angles to its long axis. From its origin it becomes gradually narrower, passes inward and forward, and then curves upward and forward to join the descending ramus of the pubes. It thus forms the bony arch which encloses the lower posterior third of the obturator foramen. It presents an external (ventral) and an internal (dorsal) surface and a ventral and a dorsal border.

The **external surface** of the ramus of the ischium (Fig. 518) is the continuation inward of the lower part of the external surface of the body of the bone. Its emarginate upper edge is the **dorsal border** bounding the obturator foramen. It is separated from the pubes by an imaginary transverse line at the lower third of the foramen. Below, it is limited by the arcuate **ventral border**, which is formed behind by the union of the two lips of the tuberosity, then turns upward at the inner end, and joins the corresponding part of the border of the ramus of the other ischium to form the lower part of the median

FIG. 520.

*Crest of Ilium.*



LEFT INNOMINATE BONE, DORSAL ASPECT.

anterior union between the two innominates known as the **symphysis**. The external surface is wide and concave in its outer part, narrow and convex in its ascending part. It faces downward, forward, and outward; it gives origin to part of the quadratus femoris muscle and to part of the obturator externus.

The **internal surface** of the ramus of the ischium (Figs. 519, 520) is similar in shape to the outer surface, but is somewhat flatter, and forms the lower posterior lateral wall of the pelvic cavity. The median ascending part of the ramus is often marked off from the rest by a **ridge** which crosses the surface obliquely from the median lower part of the obturator foramen to the posterior end of the symphysis. The part lateral to this ridge faces upward, inward, and backward, and the part on its median side faces upward and backward only. A wide strip of the surface along the ventral border gives origin to part of the obturator internus muscle, and just within the same border, at its middle, is a point of attachment for the crus penis.

The **tuberosity** of the ischium lies at the posterior dorsal angle of the bone (Fig. 517). It presents an external, or ventral, lip and an internal, or dorsal, lip. The two lips begin at the outer side, separate widely to include an intermediate surface, and then approach each other and are continuous on the inner side with the ventral border of the ramus (Fig. 520). The triangular **posterior surface** is convex and rough; since it faces upward, backward, and inward, it appears to be formed at the expense of the inner surfaces of the body and ramus of the ischium. It gives attachment to the origins of the following muscles: to the biceps femoris at the lateral greatest swelling, then to the semitendinosus by a smaller more median area, and to the semimembranosus for the rest of its extent. Its outer lip bounds the area of origin of the quadratus femoris on the external surface of the body of the ramus; its inner lip bounds the dorsal part of the area of origin of the obturator internus.

The **Pubes** is the smallest of the three elements of the innominate. It is L-shaped, and bounds the median anterior part of the obturator foramen, joining the ilium and the body of the ischium above and the ascending ramus of the ischium below. By its union at the symphysis with the opposite pubes it forms the anterior part of the ventral wall of the pelvic cavity. It may be divided into three parts, a body, a horizontal ramus, and an ascending ramus.



The **body** of the pubes occupies the angle of the bone. It is thin and quadrilateral. On the outer side it is continuous with the horizontal ramus; on the median side it joins the body of the other pubes; and below, posteriorly, it is continuous with the descending ramus.

It has a flat **external (ventral)** surface (Fig. 518), which affords attachment to the adductor femoris muscle.

Its **internal (dorsal)** surface (Fig. 519) is flat from side to side, slightly convex from above downward, and forms the anterior median part of the ventral wall of the pelvic cavity.

Its **median border** is rough, and by means of an intervening plate of cartilage forms, with the opposite bone, part of the symphysis.

The **posterior border** is emarginate, and is part of the edge of the obturator foramen.

Its **anterior border** is transverse; near its median end is a more or less well developed projection, the **spine** of the pubes, to which are attached the rectus abdominis and some fibres of the external oblique muscle of the abdominal wall (Fig. 518). The portion of the border median to the spine forms with its fellow of the opposite side the **crest** of the pubes. Lateral to the spine the border is sometimes swollen and passes into the anterior border of the horizontal ramus.

The **horizontal ramus** extends upward and outward from the body, and includes at its outer end the separate ossification known as the cotyloid bone. In its median part it is slender and sometimes triangular on cross-section, but it becomes wider and more flattened as it passes outward. It presents ventral and dorsal surfaces.

The **ventral (external)** surface (Fig. 518) is bounded in front by the continuation, downward from the ilium, of the faintly emarginate ilio-pectineal line, and behind by the deeply emarginate border which forms the edge of the obturator foramen. On the outer side it can be divided only artificially, in the adult, from the ilium and ischium on the imaginary lines already described. It is convex from side to side and also from above downward; it faces downward and outward. Its external outer part is excavated to form a fifth of the acetabulum. In some specimens a **ridge** which runs parallel to the long axis of the ramus divides the inner part of the ventral surface into anterior and posterior parts, thereby producing the triangular cross-section. The ventral surface gives origin to part of the adductor femoris muscle. On the lower part of the ilio-pectineal line are attached fibres of the

external oblique, and a prominence higher up and more or less distinct affords origin for the pectineus muscle.

The **dorsal (internal) surface** is concave from side to side and slightly convex from above downward. It is smooth, and forms one-half of the anterior transverse part of the ventral wall of the pelvic cavity, affording attachment to parts of the obturator internus and pubio-caudal muscles.

The **descending ramus** of the pubes is the small remaining portion which extends downward and backward from the body to meet the ascending ramus of the ischium. It is wider above than below.

Its thin and emarginate **outer border** bounds the obturator foramen, and its thick, straight, and roughened **median border** joins its fellow to assist in the formation of the symphysis.

Its **ventral surface** (Fig. 518) slopes upward, outward, and backward, facing downward, outward, and forward. It is smooth, and is occupied by the origin of the adductor femoris and obturator externus muscles.

Its **dorsal surface** (Fig. 520) faces upward and backward, and affords attachment to parts of the pubio-caudal and obturator internus muscles. The point of junction of the descending ramus with the ramus of the ischium is often marked by a tubercle on the outer or obturator border.

The **acetabulum**, or **cotyloid cavity**, is a hemispherical excavation on the outer aspect of the innominate bone somewhat below the centre. It is bounded by a rim, prominent throughout except at the point nearest the obturator foramen, where a groove on the ischium passes upward into the cavity and produces the **cotyloid notch**. This notch is bridged by a ligament to form a canal for the passage of the vessels and the nerves to the hip-joint. The walls of the acetabulum are smooth, and covered with articular cartilage except at a circular space at the centre of the floor, which is continued downward and inward as a wide band leading to the cotyloid notch. In this region the surface of the cavity is depressed and rough to give attachment to a cushion of fat and also to the ligamentum teres from the head of the femur. The capsular ligament of the hip-joint is attached to the innominate at some little distance from the rim of the acetabulum. Of the acetabulum, the ischium supplies three-fifths, the ilium one-fifth, and the cotyloid bone, or pubes, one-fifth.

The **obturator foramen** is a large oval opening surrounded by the three elements of the innominate. Its long axis is about one-third greater than the transverse axis, and is nearly parallel with the long axis of the bone. It is closed by the obturator muscles.

**Nomenclature.**—The word innominate is from the Latin *innominatum*, meaning without a name, derived from *anonymon*. Galen in describing this bone gave it no name, and Vesalius, in a commentary on the passage, asserted that some people called it a bone without a name. A synonym is *os coxæ*, which, in the Middle Ages, was applied to the thigh bone or femur, while the hip bone was called *os anchæ*, whence we get the word haunch. The French equivalent is *os coxal* or *os iliaque*; the German, *das Hüftbein*. The parts of the hip bone have received various names. The term ilium, introduced by Vesalius as *os ilium*, is the genitive plural of *ilia*, from the obsolete *ile*, meaning soft part; *os ilium* therefore denotes the bone of the soft parts,—that is, of the belly.<sup>1</sup> *Os ilei*, also used, is derived from *ileum*, a part of the small intestine, and hence means the bone of the ileum, which rests upon it. The Germans use *das Darmbein*, a translation of *os ilei*; the French use *l'ilion*.

Ischium is the Latin for the Greek *ischion*, derived from *ischein*, to support. It was introduced by Galen for the part of the hip bone which supports the body when seated. It is used by Homer for the hip-joint, by others for the whole hip bone, for the head of the femur, or even for the buttock. The German word is *das Sitzbein*; the French, *l'ischion*.

Pubes is Latin, meaning primarily the hair which appears on the body at puberty, and secondarily the genitalia, whence comes *os pubis*, or *os pubes*. The Germans employ *das Schambein*; the French, *le pubis*.

**Determination.**—If the acetabulum be held toward the student with the obturator foramen below it, the ilium will point to the side to which the bone belongs.

**Articulations.**—The innominate articulates with the sacrum, the femur, and the other innominate.

**Muscular Attachments.**—The following muscles are attached to the innominate bone: on the crest of the ilium, the **sartorius** and the **tensor vaginæ femoris**: on the external surface, to the ilium, the **gluteus medius**, the **gluteus minimus**, the **gluteus quartus**, the **rectus femoris**, the **internal oblique**, the **iliacus**, and the **psoas parvus**; to the ischium, the **gluteus minimus**, the **gemelli**, the **quadratus femoris**,

<sup>1</sup> Hyrtl, *Onomatologia Anatomica*, 1880, p. 266.

the biceps, the semitendinosus, the semimembranosus, and the obturator externus; to the pubes, the pectineus, the external oblique, the adductor, and the obturator externus: on the internal surface, to the ilium, the erector spinæ, the iliacus, and the ilio-caudal; to the ischium, the levator ani, the crus penis, and the obturator internus; to the pubes, the pubio-caudal and the obturator internus.



**Blood-Supply.**—The innominate receives its blood-supply from different vessels, principally branches of the external and the internal iliac. The most important, perhaps, of these are the branch from the obturator artery, piercing the external surface of the ilium at its lower part, near the anterior border; the ischiac branch, supplying the iliac dorsal external surface; and the branch from the deep femoral, entering the ischium on the external surface below the acetabulum.

**Ossification.**—The innominate is developed from four primary centres and several secondary centres of ossification. The first centre to appear is that for the ilium; this is followed by the centre for the ischium and the centre for the pubes. To these are added the centre

for the cotyloid bone, and ossifications in the tuberosity and margin of the ischial ramus, the crest, and the auricular surface. Further study may reveal additional centres at the symphysis or in the secondary processes of the bone.

#### VARIATIONS IN THE INNOMINATE BONE.

##### VARIATIONS IN SIZE.

The measurements of the innominate bone are taken as follows :

The maximum length is the distance from the crest to the tuberosity.

The length of the ischium is the distance from the upper border of the rough space in the acetabulum to the lowest point on the tuberosity.

The length of the ilium is the distance from the highest point of the crest to the upper border of the rough space in the acetabulum.

The length of the pubes is the distance from the middle of the upper border of the rough space in the acetabulum to the upper end of the symphysis.

The length of the symphysis is the length of the straight inner edge of the innominate.

The width of the ilium is the transverse diameter at the level of the auricular surface.

The width of the ischium is the transverse diameter at the level of the spine.

The long diameter of the obturator foramen is taken parallel with the symphysis.

The short diameter of the obturator foramen is taken at right angles to the long diameter and through its middle point.

The angle which the symphysis forms with the ilium is the angle formed by the meeting of the straight line of the symphysis with a straight line drawn from the anterior part of the crest of the ilium to the inner end of the pubes.

The angle of the ilium with the plane of the obturator foramen was taken by placing the innominate on a flat surface in such manner that the ventral aspects of the tuberosity and of the anterior and posterior ends of the symphysis were in contact with the surface. The vertical distance from the surface to the anterior superior spine of the ilium was measured, and also, on the surface, the distance from the tuberosity of the ischium to the lower end of the vertical line, and the angle computed from a projection on paper.

## INNOMINATE BONE.

Side.	Maximum length.	Length of ischium.	Length of ilium.	Length of pubes.	Length of symphysis.	Width of ilium.	Width of ischium.	Long diameter of obturator foramen.	Short diameter of obturator foramen.	Angle of symphysis with ilium.	Angle of ilium with plane of obturator foramen.
Left . . . . .	68	29	39	20	24	12.5	8.5	17.5	12	49	25.5
Right . . . . .	69	30	39	20	24	12.5	8	17	12	43	25.5
Left . . . . .	71	30.5	40	21	24	14	8.5	18	13	46.5	27
Right . . . . .	71.5	30	41	20	24.5	14	8.5	18	13	54.5	22
Right . . . . .	72	30	43	20	24	14	8	17	12	39	22.5
Right . . . . .	72	30	40.5	23	24.5	14	9	19	13.5	49	28
Left . . . . .	72	31	41	20.5	21	13	8	18.5	12	45.5	22.5
Right . . . . .	72.5	31	42	20	24	14	8	18	12	39	23
Left . . . . .	73	28	41	23	25	15	9	19	12	45.5	21
Right . . . . .	74.5	33	42	21	26	15	9	19	12	45	
Left . . . . .	75	30	43		26	13	8	19	13		23.5
Right . . . . .	75	31.5	44	23	25	14	9	18	12	46	29
Left . . . . .	75	32.5	44	23	27	13.5	9	19	12	47.5	27.5
Left . . . . .	75.5	32	43	22	25	14.5	13	20	13	49	24.5
Right . . . . .	75.5	32	42	22	26	14.5	8	20	13	44.5	25.5
Left . . . . .	75.5	32.5	44	25	24	14	9	18	12	48	29
Right . . . . .	76	30.5	44		23	12.5	9	18.5	12	40	24
Left . . . . .	76	32	44	21	24	14.5	9.5	20	14	55.5	
Left . . . . .	76	32	44	22	23	13.5	9	20	13.5	43.5	
Right . . . . .	76	33	44	21	26	14.5	9	21	14	57	
Right . . . . .	76	33	44	23	26	13	9	19	13	51.5	29
Right . . . . .	77	32	45	21	25	15	9	19	13.5	38.5	21
Right . . . . .	77	34	45	23	25	14	9	21	14	49	28.5
Right . . . . .	78	32	45.5	24	28	15	10	19	13	43.5	33
Left . . . . .	78	33	45	22	25	14.5	9	21	14	44.5	20
Left . . . . .	78	35	43	27	25	16.5	9.5	22	15	47	
Left . . . . .	78.5	33			28	16	10	20	12		
Left . . . . .	79	31	45	22.5	27	15	9.5	19	14	44	
Left . . . . .	79	34	45	24	28	15	9.5	19	13	52	30.5
Left . . . . .	79	35	46	22	28	16.5	10	20	13	46.5	23
Right . . . . .	79.5	36	44	23	28	16	10	21	13	41	26.5
Left . . . . .	80	33.5	44	22.5	28	11.5	9.5	21	13	40	23.5
Left . . . . .	80	34	45	25	26.5	15	9.5	20	13	47.5	28
Left . . . . .	80	34.5	45	21	26.5	17	10	20	12.5	42	18
Right . . . . .	80	35	45	21	27	17	10	20	12.5	47	20
Right . . . . .	80	35	45	22	26	17	10	20	13	46	22.5
Left . . . . .	80	36	45	23	28	16	10.5	19	12	46	20.5
Right . . . . .	80.5	33	46	25	26	11	10	21	15	51	24.5
Left . . . . .	80.5	34	47	22	26	15	14	20	12.5	45.5	
Right . . . . .	81	32	48	22	26	15.5	9	20	12.5	48	
Left . . . . .	81	34	46	24	27	16.5	9	20	13.5		28
Right . . . . .	81	34	47	23	26	14	8	20	15	44.5	25
Left . . . . .	81	35	46	24	28	17.5	10	21	14	50.5	26
Left . . . . .	81.5	34	46	23	26	14	8.5	20	14	41.5	26.5
Right . . . . .	81.5	36	47.5	23	28	16	10.5	20.5	12	45.5	22.5
Left . . . . .	82	36	47	23	28	16	10.5	20	12.5	44	22
Left . . . . .	82	36	46	22	26.5	15	10	19	12	40	19.5
Right . . . . .	83	36		23	26	15	10.5	20	13	48.5	
Left . . . . .	83	36	46	22	25.5	15	10	19	13	37	
Left . . . . .	83	37	48		27	16	10	20	13	39	
Right . . . . .	83.5	36	48	23	25	15.5	9.5	19	14	41.5	
Left . . . . .	85	35.5	49		29	18	11	19	12	40	25.5
Left . . . . .	85	36	49		26	15.5	10	20	13.5	39.5	26.5
Right . . . . .	85	37	49		24	11	10	20	13	39	19
Right . . . . .	85.5	37	49.5		29	18	11	19	12	38	26.5
Left . . . . .	86	38	49	23	29	18	12	21	12	27.5	23.5
Right . . . . .	86	39	48		27	17	10.5	22	14	47.5	21.5
Right . . . . .	87	37	50	23.5	29	18	12	20	12	40	22
Left . . . . .	88	40	51	24	32	19	11	22	15	48.5	27.5

The relations between the length of the innominate and the length of the ilium or ischium may be represented by indices obtained by fixing the length of the innominate at 100 and making the proportion, innominate length : iliac length :: 100 :  $x$ . The iliac length index, therefore, equals  $\frac{\text{iliac length} \times 100}{\text{innominate length}}$ ; for example,  $\frac{39 \times 100}{68} = 57$ .

I have found no noteworthy case of variations in form or development, nor have I detected in the innominate any well-marked sexual characters.

### HUMAN INNOMINATE.

The innominate in man has a different form from the innominate in the cat; it is lower and broader. The part of the ilium above the ilio-pectineal line is strongly developed (Fig. 522), forming fully one-half of the entire bone, and flaring outward to form with its fellow of the opposite side a large false pelvis. It is very evident that this difference is due to the assumption by man of the upright posture, with the consequent weight of the abdominal viscera and the traction of the abdominal wall on the upper part of the haunch bones. The area by which the innominate articulates with the sacrum is on the inner side of a triangular posterior prolongation which is very prominent because of the great depth of the greater sacro-sciatic notch. The part of the bone below the ilio-pectineal line forming the wall of the true pelvis is triangular, and not quadrate, as in the cat. The change of position of the human pelvis, due to the changed posture of the whole body, has, of course, brought the long axis of the bone more nearly vertical.

The crest of the ilium is very prominent and arcuate, and the distance between the anterior and posterior superior spines is much increased; hence the distance between the superior and inferior spines, in front and behind, is correspondingly decreased.

To the iliac crest are attached by its outer lip the fascia lata, and the external oblique and latissimus dorsi muscles; to the inner lip are attached the transversalis, quadratus lumborum, and erector spineæ muscles; to the anterior half of the space between the lips is fastened the internal oblique muscle.

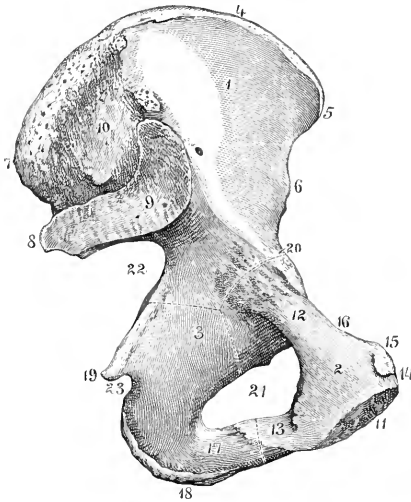
The anterior inferior spine is just above the acetabulum, and not separated from it, as in the cat, by a long border. It gives origin to the rectus femoris muscle.

The anterior superior spine is prominent, and, with the part of the border below,—namely, the superior iliac notch,—affords attachment to the sartorius muscle.

The fan-shaped outer surface, or dorsum, of the ilium (Fig. 523) is undulating, and presents three gluteal ridges.

The superior gluteal ridge runs from the posterior part of the crest to the top of the greater sacro-sciatic notch; the middle gluteal ridge

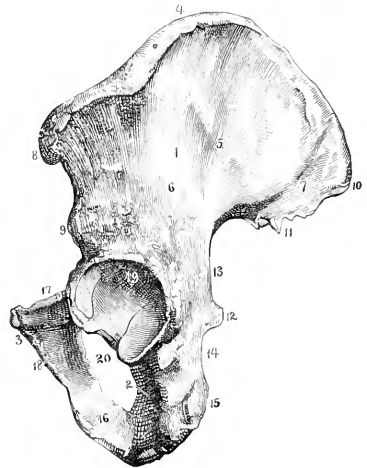
FIG. 522.



INNER VIEW OF THE LEFT HIP BONE.

The dotted line indicates its division into three parts: 1. the ilium; 2. the pubes; and 3. the ischium. (1, iliac fossa) 4, crest of the ilium; 5, 6, anterior superior and inferior spines; 7, 8, posterior superior and inferior spines; 9, auricular surface for the sacrum; 10, rough tuberosity for the attachment of ligaments. (2, body of the pubes) 11, symphysis; 12, horizontal ramus; 13, descending ramus; 14, pubic crest; 15, pubic spine; 16, pectineal line. (3, plane of the ischium) 17, ramus of the ischium; 18, tuberosity; 19, spine of the ischium; 20, ilio-pubic ridge; 21, obturator foramen; 22, greater sciatic notch; 23, lesser sciatic notch.

FIG. 523.



OUTER VIEW OF THE LEFT HIP BONE.

1, ilium; 2, ischium; 3, pubes. (1, dorsal surface of the ilium) 4, crest of the ilium; 5, 6, 7, middle, inferior, and superior curved lines or gluteal ridge; 8, 9, anterior superior and inferior spines; 10, 11, posterior superior and inferior spines. (2, body of the ischium) 12, spine of the ischium; 13, greater sciatic notch; 14, lesser sciatic notch; 15, tuberosity of the ischium; 16, ramus of the ischium. (3, body of the pubes) 17, horizontal ramus of the pubes; 18, descending ramus; 19, acetabulum; 20, obturator foramen.

curves backward from the crest at a point above the anterior superior spine to the sciatic notch; the inferior gluteal ridge passes from the anterior superior spine to the inferior end of the sciatic notch. In the area behind the superior ridge is attached the gluteus maximus muscle; the area between the superior and the middle ridge is occupied by the gluteus medius, with the exception of a small space in front, which affords origin to the tensor vaginæ femoris; in the area between the middle and the inferior ridge is attached the gluteus minimus. Below the lowest ridge the surface becomes convex, and forms the upper rim of the acetabulum and two-fifths of the cavity



itself. Above the rim of the acetabulum is a narrow area of origin of the rectus femoris muscle.

The **inner surface** of the ilium (Fig. 522) above and in front of the ilio-pectineal line is concave, and forms the iliac fossa for the iliac muscle; behind the line and above the greater sacro-sciatic notch is the **auricular surface** for the sacrum, surmounted by the rough **tuberosity** for ligaments. Only a small portion of the ilium extends in front of the notch and below the ilio-pectineal line to meet the ischium. To this portion is attached part of the obturator internus muscle. On the ilio-pectineal line is inserted the psoas parvus.

The **ischium** is shaped like a horseshoe, and is shorter and thicker than the ischium of the cat. It has a body and an ascending ramus. Where the body joins the ilium on the inner surface is a variable ilio-ischial line. The **spine** is sharp and triangular; it is separated from the swollen **tuberosity** by the lesser sacro-sciatic notch. To the spine are fastened the gemellus superior, coccygeus, and levator ani muscles; the gemellus inferior arises below the spine; and between the two lips of the tuberosity are attached the semimembranosus, semitendinosus, and biceps femoris muscles.

Between the rim of the acetabulum and the tuberosity is the **obturator groove** for the internal obturator muscle. To the outer surface of the body of the ischium is fastened the quadratus femoris muscle, and to the outer surface of both the body and the ramus, the obturator externus and the adductor magnus.

The obturator internus muscle arises from the inner surface of the body and the ramus, and the transversus perinei from the ramus only.

The **pubes** is relatively shorter than the pubes of the cat. It has a body and horizontal and descending rami.

The body is quadrilateral; its upper surface, or **crest**, has a sharp anterior margin which presents the **pubic spine** for the attachment of Poupart's ligament, coming from the superior iliac spine. The internal angle is the **pubic angle**, between which and the spine are attached the rectus abdominis and pyramidalis muscles.

The posterior surface of the body is smooth, and continuous downward with the surface of the descending ramus and outward with the surface of the horizontal ramus. It affords attachment to the levator ani and obturator internus muscles; the latter muscle is also attached to the surfaces of the rami.

To the outer surface of the body is attached the adductor longus, and to the outer surface of the body and descending ramus are attached the adductor brevis, the gracilis, and the obturator externus.

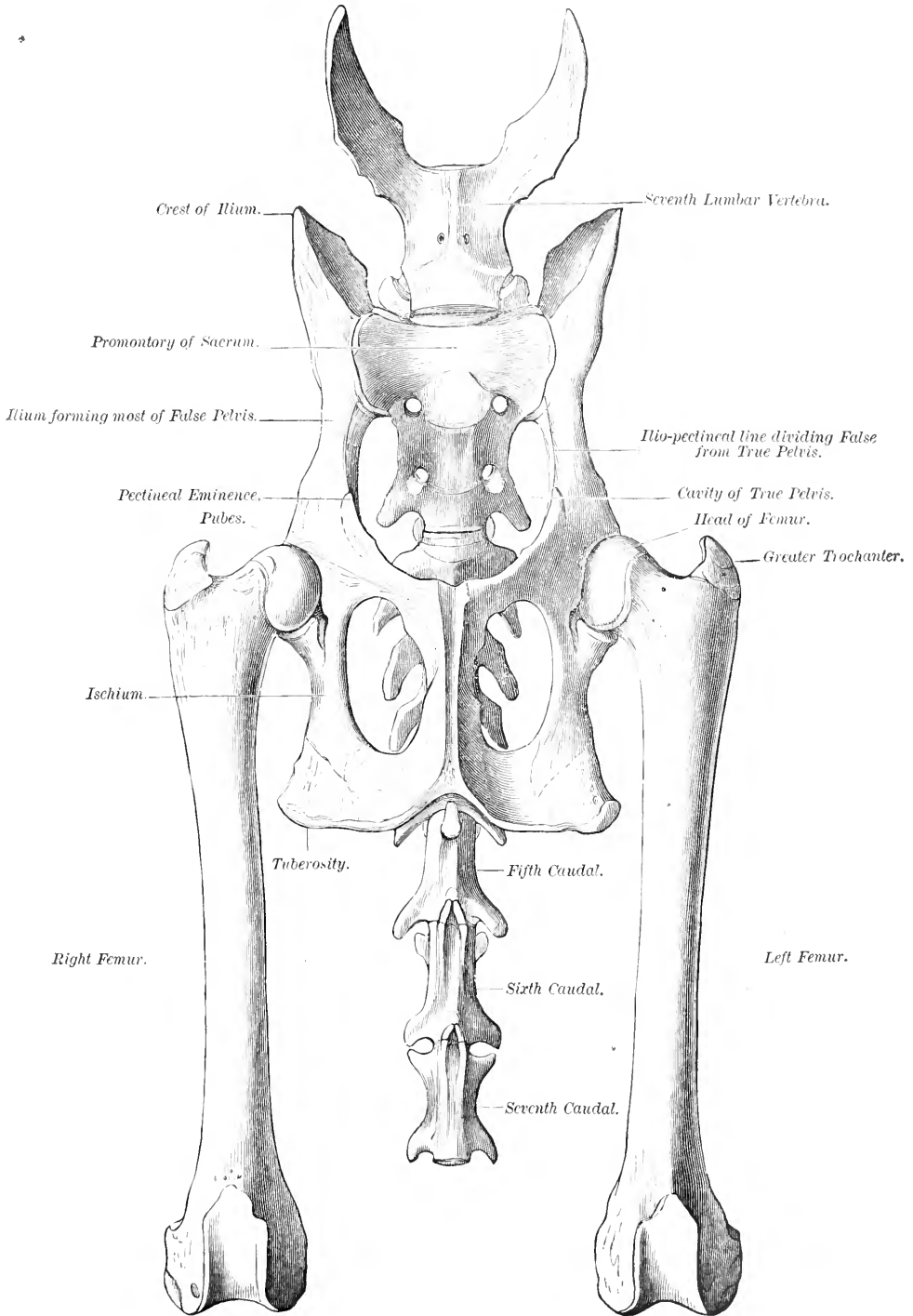
The **horizontal ramus** joins the body with the ilium. Some anatomical writers reverse these parts and call the body the horizontal ramus, and *vice versa*. This ramus forms a fifth of the acetabulum. On the inner surface, where it joins the ilium, is the **ilio-pubic ridge**, the inner end of which forms the **ilio-pectineal eminence** and is connected with the pubic spine by the continuation of the ilio-pectineal line sometimes called the **pectineal line**. The pectineus muscle arises in front of this line. The anterior border of the ramus from the spine to the acetabulum is termed the **obturator line**, inasmuch as it limits the area of origin of the obturator externus muscle. The obturator foramen is irregularly oval in the male, and triangular in the female.

### THE PELVIS.

**General Description.**—The Pelvis is the bony framework formed by the hip bones and the adjoining part of the vertebral column; it contains the posterior part of the alimentary and genito-urinary tracts. It is something more than the pelvic girdles, for, in addition to the innominate bones, it includes the sacrum and the first four caudal vertebræ. The pelvic cavity is smaller than the cranial and thoracic cavities, and its bony walls are stouter, but less complete. It may be compared to a hollow cylinder whereof the anterior end points upward and forward and the posterior end downward and backward.

The anterior ventral half of this imaginary cylinder is lacking, and the dorsal wall is complete in front for only a short distance in the region of the first sacral vertebra; for most of its extent behind, it is confined to a strip along the middle line formed by the second and third sacral and the first four caudal vertebræ. The bones which form the pelvis are all immovably united, except the four caudal vertebræ, which are capable of free movement,—not so free, however, as would seem from the mounted skeleton, since the intervals between them and the innominates are filled with muscles and ligaments. It will be noticed that in the ordinary position of the cylinder-like pelvis the immovable anterior part of the dorsal wall lies above the anterior opening in the ventral wall, and the immovable posterior part of the

FIG. 524.



THE PELVIS AND RELATED BONES, ANTERIOR VIEW.

ventral wall lies beneath the movable posterior part of the dorsal wall. In this way the least possible resistance is offered to the passage of the young through the pelvic cavity at birth. The pelvis is almost twice as long from the tuberosity of the ischium to the crest of the ilium as it is high from the crest of the pubes to one of the posterior articular processes of the sacrum. Its maximum width, at the tuberosities of the ischia, is slightly greater than its height. It is usual to divide the pelvis into two parts, the false pelvis and the true pelvis. The line of division between the two parts is seen on the inner wall only.

The **false pelvis** is almost absent in the cat, and consists of a dorsal half only. Its lateral walls are formed on each side by the part of the ilium anterior to the ilio-pectineal line; its dorsal wall is the narrow strip of the sacrum anterior to an imaginary continuation of the pectineal line upward and inward across the ventral surface of the lateral mass to the lower outer corner of the anterior articular end of the body.

The **true pelvis** comprises the greater part situated posterior to this line. It presents a cavity bounded by bony and muscular walls and having an anterior opening or inlet and a posterior opening or outlet.

The **inlet** of the pelvis is at the brim of the pelvis; it is formed on each side, from below upward, of the border of the pubes, the ilio-pectineal line, and the line of the greatest antero-posterior convexity on the sacral lateral mass. It is a regular oval opening, and its antero-posterior diameter, from the pelvic symphysis to the sacrum, is almost a fourth greater than the greatest transverse diameter, which is found between points just above the pectineal eminences. The oblique diameter is measured from the ilio-pectineal eminence of one side to the sacro-iliac articulation on the other side. The plane of the inlet of the pelvis faces almost directly forward and only slightly downward, and is very oblique to the long axis of the general cavity of the pelvis, which runs downward and backward.

The **pelvic cavity** is almost circular in front and is triangular behind; its dorsal wall is twice as long as the ventral wall. It is bounded above by the ventral surfaces of the sacrum and of the four caudal vertebræ; at each side, in front, by the inner surface of the ilium, and behind by the inner surface of the body of the ischium. Its lower wall is formed by the pubes and the ascending ramus of the ischium. Its lateral walls are parallel, and the upper wall is,

practically, parallel with the lower wall. The pelvis contains the bladder and the last division of the bowel, called the rectum, and in the female, between them, the vagina and part of the uterus.

The outlet of the pelvis is between the body of the fifth caudal vertebra, the tuberosities, and the posterior borders of the ascending rami of the ischia. It is irregularly lozenge-shaped, pointed below and narrow above. The transverse diameter, taken between the dorsal tips of the tuberosities, is greater than the pubio-caudal diameter, which extends from the posterior termination of the symphysis of the pubes to the body of the fifth caudal. The plane of the outlet of the pelvis faces downward and backward.

The outer surface of the pelvis has been already described in the consideration of the innominate bones, of the sacrum, and of the caudal vertebrae.

**Nomenclature.**—The word pelvis is the Latin, from the Greek *pele*, for a deep, wide vessel.

#### VARIATIONS IN THE PELVIS.

##### VARIATIONS IN SIZE.

The following are the more important measurements of the pelvis.

The conjugate diameter of the brim is the distance from the median point on the cephalic edge of the sacrum to the cephalic end of the pubic symphysis.

The obstetric conjugate diameter is the *shortest* distance from the median point on the cephalic edge of the sacrum to the cephalic end of the pubic symphysis.

The diagonal conjugate diameter is the distance from the cephalic end of the sacrum to the caudal end of the pubic symphysis.

The obstetric conjugate diameter of the outlet is the distance from the caudal end of the pubic symphysis to the caudal end of the sacrum.

The transverse diameter is the width of the brim between the pectineal eminences.

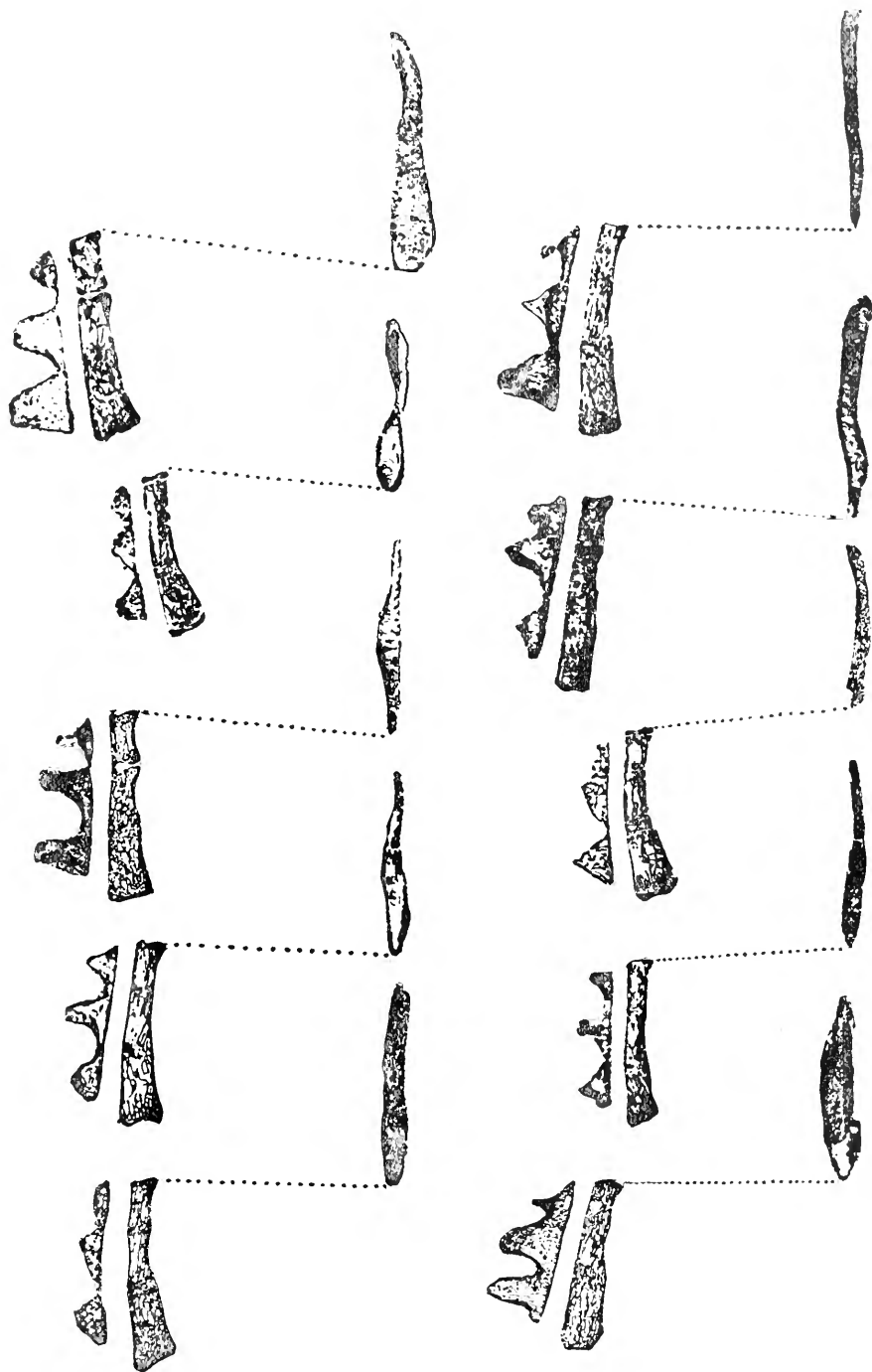
The pectineal oblique diameter is the distance from the pectineal eminence on one side to the cephalic end of the sacro-iliac articulation on the other side.

The true oblique diameter is the greatest oblique distance from the sacro-iliac articulation on one side to the brim of the pelvis on the other side.

PELVIC DIAMETERS.

	MALE.										FEMALE.										
Brim conjugate . . . . .	40	38	37.5	37	35.5	35	35	34	32	29	45	42.5	42	41	40	39	38	37	33	33	32
Obstetric conjugate . . . . .	39	37	38	37	36	35	34	33	32	29	46	44	41	42	40	38	37	36	33	33	32
Diagonal conjugate . . . . .	62	56	59	58	57	63	50	61	54	47	66	62	60.5	62	62	59	60	53	54	50	51
Obstetric conjugate of outlet . . . .	45	39	40	39	39	47	38	44	37	36.5	47	41	40	40	40	39	40	38	36	35	35
Interpectineal transverse . . . . .	30	26	29	25	26	29	19	28.5	22	20	30	28	29	27	28	27.5	30	28	27	20	22
Pectineal oblique . . . . .	R {	32	30	30	30	31	28	31	26	23.5	33	30	33	30	32	32	34	30	30	28	28
	L {	33	30.5	31	30	29	33	28	30	27	33	33	32	32.5	33.5	29	32	31	30	28	27.5
True oblique . . . . .	R {	36	36	37	32.5	33	34	32	33	30	40	37.5	36	35	38.5	35	37	35	34	30	30
	L {	35.5	35.5	36	32.5	32	36	31.5	34	30	41.5	39	36	36	38	35	36	34	33	30	30
Interspinal transverse. . . . .	27	24	23	22	25	22	19	32	20	17	23	24	24	29	28	25	25	26	22	19	19
Width at acetabulum . . . . .	48	39.5	40	40	40	43	34	49	36	33	43	40.5	41	37	42	41	41	40	38	33.5	33
Width at tuberosities . . . . .	47	41	46.5	41	44	50	37	53	41	31	43	43	44	43.5	45	49	45	38	36	33.5	36
Width at anterior superior spines . .	46	39	43	40	42	47	33	42	42	29	39	43	41	40	42	43	42	42	36	33.5	34
Width at anterior inferior spines . .	41	35	38	35	36.5	38	29	41	35.5	26.5	38	38	36	35	38	38	35	36	32	29	30
Caudal angle . . . . .	80°	85.5°	79°	94°	89°	100°	88°	80°	87°	87°	89°	83°	83°	89°	83°	87°	86°	83°	93°	86.5°	93°
Cephalic angle . . . . .	119°	125°	118°	133°	132°	137°	126°	139°	129°	127°	121.5°	121°	119°	130°	122°	122°	127°	122°	132°	126°	138°

FIG. 525.



LONGITUDINAL MEDIAN SECTIONS OF THE PELVIS, UPPER ROW, MALE Pelves; LOWER ROW, FEMALE Pelves.

(Printed from the bones.)

The interspinal diameter is the distance between the ischial spines.

The width of the pelvis is taken at the following points: (1) maximum width at acetabula; (2) between the outer edges of the ischial tuberosities; (3) at the anterior superior iliac spines; (4) at the anterior inferior iliac spines.

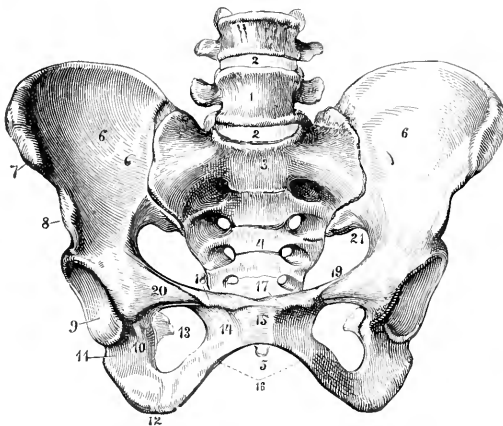
The caudal angle is the angle formed by the meeting of the plane of the symphysis of the pubes with a transverse plane passing through the cephalic end of the symphysis and the caudal end of the sacrum.

The cephalic angle is the angle formed by the meeting of the plane of the symphysis with a transverse plane passing through the cephalic end of the sacrum.

#### VARIATIONS IN FORM AND DEVELOPMENT.

The variations in the pelvis which depend upon the sex of the animal appear to be very slight. They were studied upon male and female pelvises from which the soft parts had been removed with care so that the sacro-iliac articulations might be undisturbed. As soon

FIG. 526.



FRONT VIEW OF A FEMALE PELVIS.

1, last lumbar vertebra; 2, intervertebral ligaments; 3, sacrum, the figure being placed below its promontory; 4, transverse lines indicating the original separation of the sacrum into five vertebral segments; 5, end of the coccyx; 6, iliac fossa; 7, 8, anterior superior and inferior spines; 9, acetabulum; 10, cotyloid notch; 11, body of the ischium; 12, tuberosity of the ischium; 13, spine of the ischium, seen through the obturator foramen; 14, body of the pubes; 15, symphysis of the pubes; 16, arch of the pubes; 17, crest of the pubes; 18, spine of the pubes; 19, pectineal line; 20, ilio-pubic eminence; 21, great sacro-sciatic notch.

as the pelvises had dried without distortion, they were bisected longitudinally, and the halves embedded in plaster of Paris in such manner that only the median surface was visible. From this surface, when slightly ground and polished, prints were taken as from a wood-cut. A few of these prints are given in Fig. 525. It will be noticed that



when all the symphyses are placed horizontally the anterior end of the pubes, as a rule, projects further forward under the sacrum in the male pelvis than in the female.

### HUMAN PELVIS.

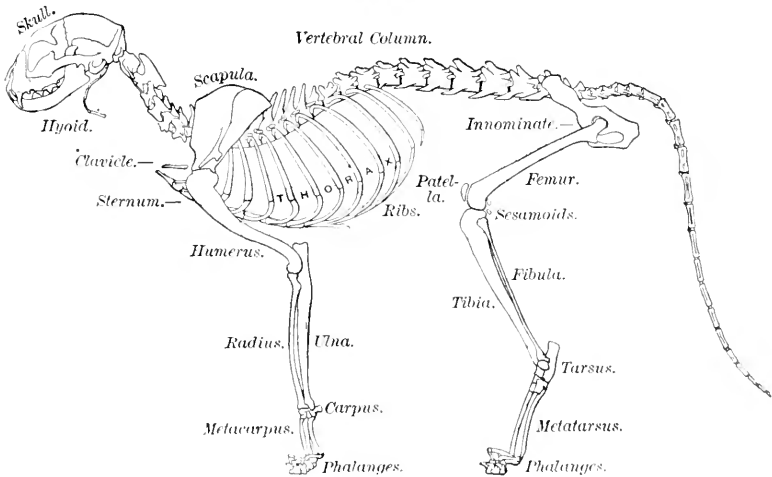
The differences between the human pelvis (Fig. 526) and the pelvis of the cat have already been pointed out in the consideration of the constituent bones, and can be seen by a comparison of the specimen and figures. The diameters of the human pelvis differ in the sexes :

	Male.	Female.
Breadth of pelvis at iliac crests . . . . .	10 to 11 $\frac{5}{8}$ in.	9 $\frac{1}{4}$ to 11 $\frac{3}{4}$ in.
Conjugate diameter of inlet . . . . .	4 " 4 $\frac{1}{4}$ "	4 $\frac{1}{8}$ " 5 "
Transverse diameter of inlet . . . . .	4 $\frac{5}{8}$ " 5 $\frac{1}{8}$ "	5 $\frac{1}{4}$ " 5 $\frac{3}{4}$ "
Oblique diameter of inlet . . . . .	5 " 5 "	5 $\frac{1}{8}$ " 5 $\frac{1}{2}$ "
Depth of pelvic cavity behind . . . . .	4 $\frac{1}{2}$ " 4 $\frac{3}{4}$ "	4 $\frac{1}{4}$ " 4 $\frac{3}{4}$ "
Depth of pelvic cavity laterally . . . . .	4 $\frac{1}{2}$ " 4 $\frac{5}{8}$ "	3 $\frac{1}{2}$ " 3 $\frac{3}{4}$ "
Depth of pelvic cavity in front . . . . .	1 $\frac{3}{4}$ " 2 "	1 $\frac{5}{8}$ " 1 $\frac{7}{8}$ "
Conjugate diameter of outlet . . . . .	3 $\frac{1}{2}$ " 4 $\frac{1}{2}$ "	3 $\frac{1}{2}$ " 5 "
Transverse diameter of outlet . . . . .	3 $\frac{1}{8}$ " 4 "	3 $\frac{3}{4}$ " 5 "

### THE FEMUR.

**General Description.**—The Femur is the single bone of the thigh (Fig. 527). It articulates above by a ball-and-socket joint with the

FIG. 527.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

innominate bone, and below by a hinge joint with the larger bone of the leg, the tibia. With the exception of the tibia and the ulna, it is

the longest bone in the skeleton. Like the humerus, it has an extended range of motion, but when the animal is standing at rest its direction is more or less oblique from above downward and forward. The femur is almost cylindrical for most of its length, which is twelve to fourteen times its average width, but is expanded at the upper and lower ends, where muscles and ligaments are attached around the joints. It may be divided into three parts, the upper extremity, the shaft, and the lower extremity.

The **Upper Extremity** (Fig. 528) is not sharply divided from the rest of the bone; it is, however, more than twice as wide as the shaft, but from before backward very little if at all thicker. It supports three well-marked prominences, the head with its neck and the two trochanters.

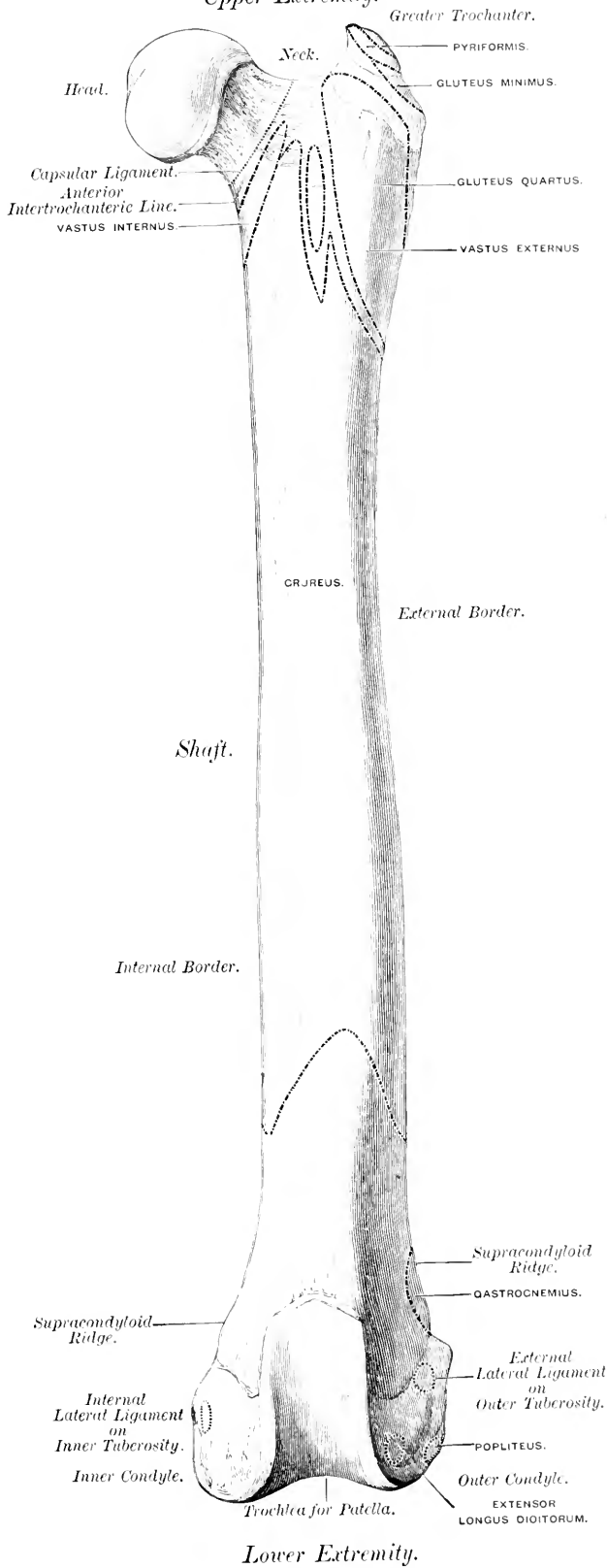
The **head** is the inner angle of the upper end of the femur prolonged upward, forward, and inward. It is nearly globular, smooth, and covered with cartilage. Its inner surface is marked just behind and below the middle by a deep rounded or oval pit, wherein is inserted the ligamentum teres, or round ligament, which unites the bone to the acetabulum of the innominate. The smooth surface of the head is distinctly defined in front and below from the neck, but behind and above it is prolonged for some distance outward on the neck.

The **neck** separates the head from the shaft, and affords insertion for the capsular ligament of the hip-joint. It is a constriction which, inasmuch as the head is almost at right angles to the rest of the upper extremity, encircles the bone in a plane very little oblique to the plane of the long axis of the shaft. The neck passes above outward, almost horizontally, to the greater trochanter; in front and on the inside it is continuous with the anterior and inner surfaces of the shaft; behind it is separated from the greater trochanter by the **digital fossa**, and from the shaft by the posterior intertrochanteric line and the lesser trochanter.

The **greater trochanter** is the extension upward, outward, and backward of the external angle of the upper end of the bone. It is pyramidal in shape; the base of the pyramid is applied to the shaft and directed downward and inward; the apex rises nearly as high as the head of the femur, and points outward, upward, and forward. The trochanter is sharply defined in front from the shaft by a somewhat irregular elevated line, which runs obliquely outward and downward

FIG. 528.

*Upper Extremity.*

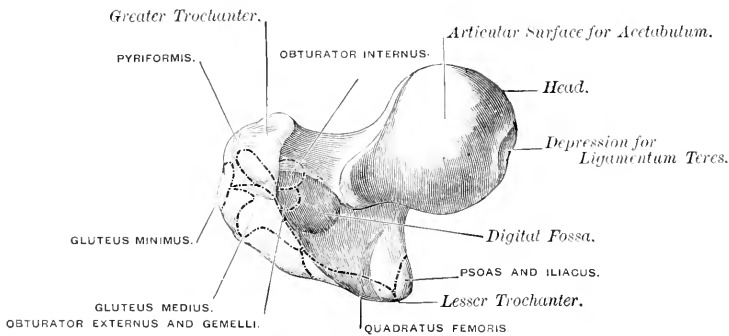


*Lower Extremity.*

LEFT FEMUR, ANTERIOR ASPECT.

and is continued on the shaft proper as the external border. It marks the upper end of the insertion of the vastus externus muscle. Above this elevated line on the trochanter is a narrow roughened area which is free from direct muscular attachment. Above this space, on the anterior surface of the apex of the trochanter, is the area for the attachment of the gluteus minimus and pyriformis muscles (Fig. 529).

FIG. 529.



LEFT FEMUR, PROXIMAL ASPECT OF UPPER EXTREMITY.

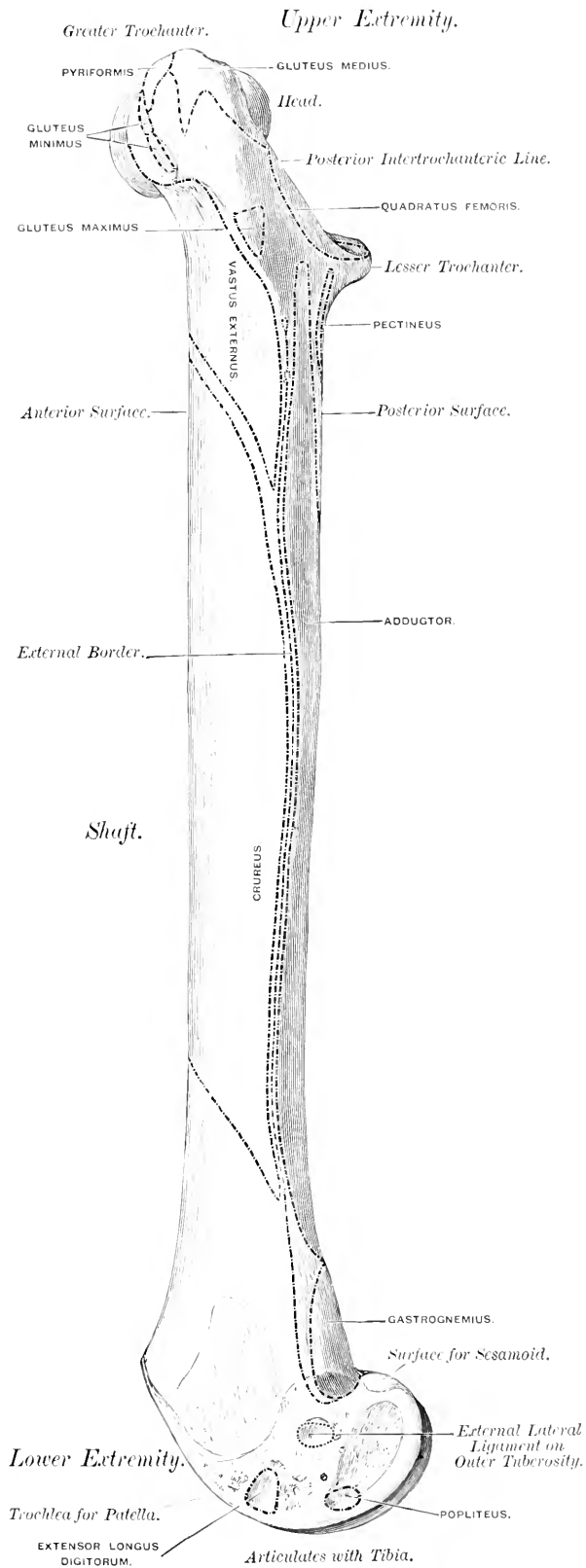
The outer surface of the greater trochanter (Fig. 530) is quadrilateral, convex from above downward and from side to side, and faces backward as well as outward. It is smooth, and at its upper part affords insertion to the gluteus medius muscle, below which, just behind the oblique elevated line mentioned above, may be seen in strongly developed bones a shield-shaped, roughened surface for the upper and larger attachment of the gluteus maximus muscle.

The upper part of the posterior surface of the trochanter contains a deep oval pit, the *digital*<sup>1</sup> or trochanteric fossa, which is directed outward and forward, and affords attachment to the tendon of the obturator internus above and the tendon of the obturator externus and gemelli muscles below. The pit is separated from the outer surface of the trochanter by a sharp crest, which runs downward and slightly inward and then turns inward at right angles to join the lower trochanter. This crest is known as the posterior intertrochanteric line. On its upper part is the inner edge of the area of insertion of the gluteus medius, and below this, all the way down to the lesser trochanter, is inserted the quadratus femoris muscle.

The lesser trochanter is placed much lower than the greater

<sup>1</sup> From *digitus*, a finger, because in the human femur the fossa is large enough to admit the end of the finger.

FIG. 530.



LEFT FEMUR, OUTER ASPECT.

trochanter on the inner edge of the posterior surface, where the upper extremity joins the shaft. It is a small, pointed tuberosity connected with the greater trochanter externally and above by the posterior intertrochanteric line; its upper and inner surfaces pass into the posterior and inner surfaces of the neck of the femur, and its lower surface is continued on the posterior surface of the shaft. On its apex is inserted the tendon of the combined psoas and iliacus muscles.

The **anterior intertrochanteric line** begins as a faint ridge on the anterior surface of the upper extremity, a little below the superior edge of the neck, and runs obliquely downward and inward to join the internal limit of the linea aspera below the lesser trochanter on the posterior internal aspect of the bone. It marks the upper border of the area of origin of the vastus externus muscle and part of the attachment of the capsular ligament.

The **Shaft** is nearly straight, or very slightly curved from before backward. It is of almost uniform diameter, slightly narrower above the middle and expanding above and below as it passes into the extremities. On cross-section, just below the lesser trochanter it is triangular; the base of the triangle represents the anterior surface, and the apex is behind and on the inside at the inner branch of the rough line on the posterior surface; a transverse section taken at the junction of the upper or lower third with the middle third is oval, the transverse diameter being about one-sixth greater than the anteroposterior diameter. The shaft presents an anterior and a posterior surface, separated by an external and an internal border.

The **external border** separates the outer parts of the anterior and the posterior surface. It begins at the lower end of the outer edge of the greater trochanter, is directed almost straight downward, and ends in the **external supracondyloid ridge** of the lower extremity.

The external border (Fig. 530) lies much nearer the posterior part of the bone than the internal, and affords attachment by its entire length to a broad sheet of the deep fascia of the thigh, known as the fascia lata, with which are blended tendinous slips from the gluteus maximus and the aponeurosis of the tensor vaginæ femoris muscle. The fascia lata separates the areas of origin of the vastus externus and crureus muscles from the area of insertion of the adductor femoris muscle.

The **internal border** (Fig. 531) is not distinctly marked in its

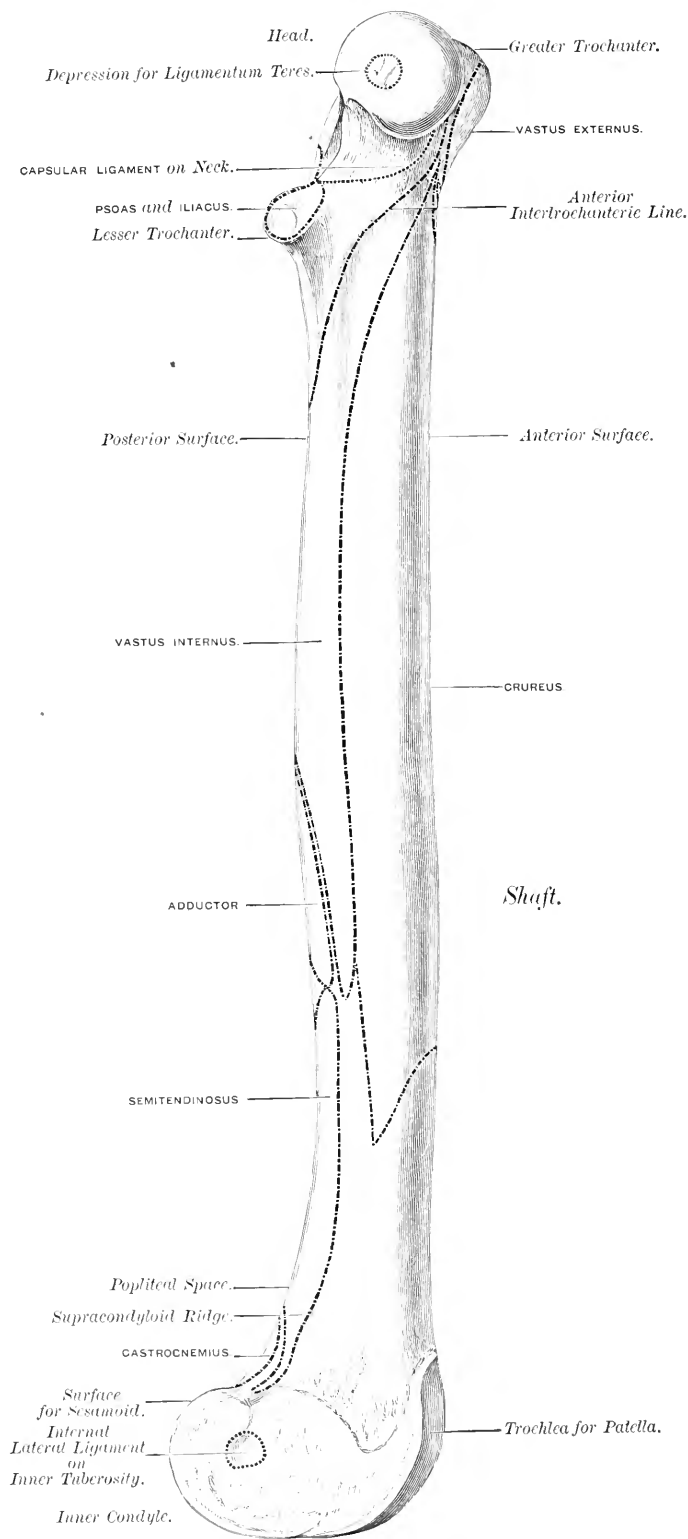
upper part. It begins on the inside of the neck, very near the front aspect of the bone, on a level with the lesser trochanter, and is continued straight down to the lower fourth, where it turns gradually backward to become the **internal supracondyloid ridge** of the lower extremity. Through its entire course it lies much nearer the anterior than the posterior aspect of the bone.

The **anterior surface** (Fig. 528) lies between the internal and external borders. It is straight from above downward, and strongly convex from side to side. Owing to the posterior situation of the external border and the anterior situation of the internal border in the upper two-thirds of the bone, in this region the greater part of the anterior surface faces forward and outward; in the lower third the surface is more evenly convex, and faces both outward and inward as well as forward. The upper part, where it passes into the surface of the upper extremity, is rough and marked by foramina for small veins; the middle part is smooth, and the lower part ends in front at the **trochlea** of the inferior extremity, and is continued on the sides to form the lateral surfaces of its internal and external tuberosities. On the upper part of the anterior surface in the middle line is the small area of insertion of the tendon of the **gluteus quartus** muscle. To the outside of this area is the triangular area of origin of the **vastus externus**, and below and to the inside the common area of origin of the **crureus** and **vastus internus** muscles. The rest of the anterior surface, down to the lower fifth, gives attachment to the **crureus** and **vastus internus**.

The **posterior surface** (Fig. 532) of the femur is convex from side to side, especially above. It is nearly straight from above downward, but at the lower end inclines somewhat backward and downward. Its upper part faces inward as well as backward, and the lower part faces directly backward. It is divided into three areas by the **linea aspera**, an elevated line, sometimes called the posterior border.

The **linea aspera** begins below at the lower fourth of the internal border of the bone, and runs obliquely upward and outward, to end in the external border at the greater trochanter. A little above the middle of its course it gives off another line, which runs directly upward and below the lesser trochanter becomes continuous with the anterior intertrochanteric line. The lower part of the **linea aspera** is well marked and elevated, and separates the areas of attachment of the

FIG. 531.  
*Upper Extremity.*



*Lower Extremity.*

LEFT FEMUR, INNER ASPECT.



adductor and vastus internus muscles. Of its superior two branches, the outer branch is low and wide, and has the appearance of a wide rough area for the attachment of the pectineus muscle, while the inner branch is not so prominent, and marks the upper part of the posterior boundary of the area of origin of the vastus internus. Near the middle of the linea aspera is the **foramen** for the nutrient artery of the shaft, which pierces the compact tissue of the bone obliquely toward the upper extremity.

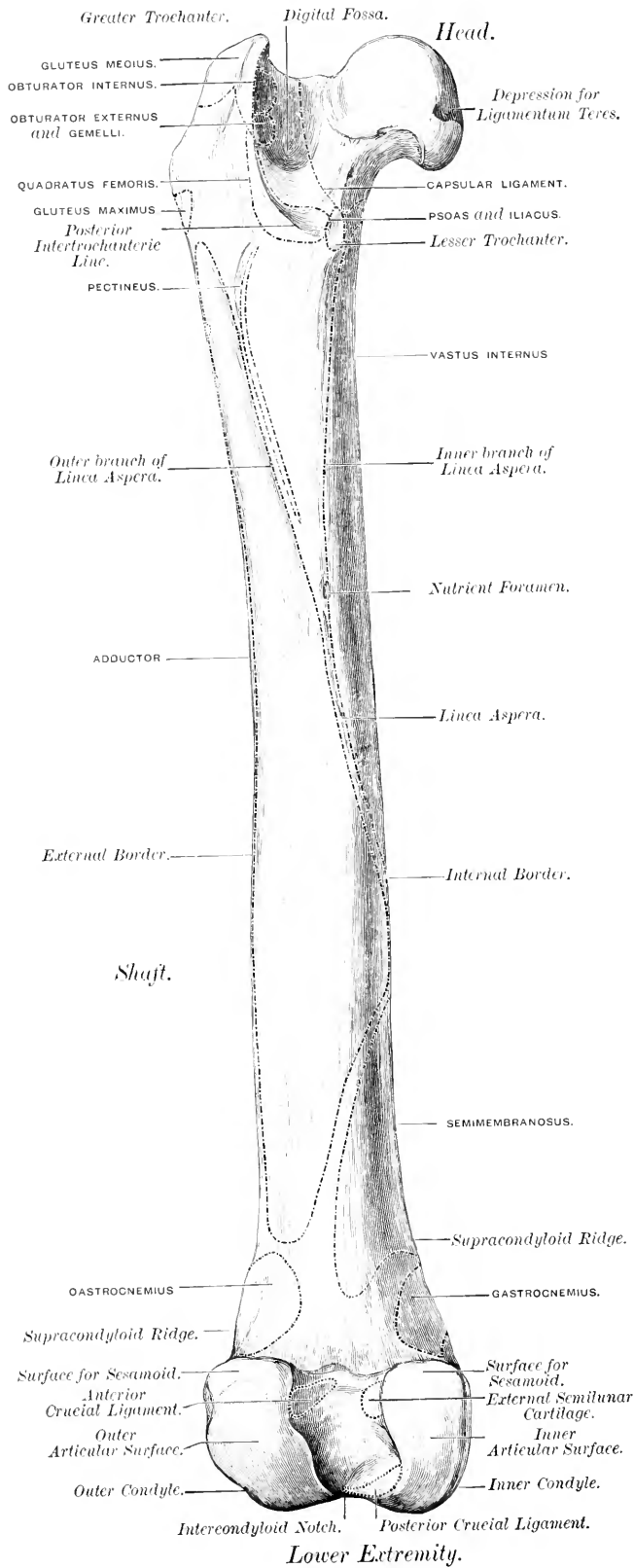
The triangular space at the upper part of the posterior surface between the two branches of the linea aspera is free from muscular attachment. At the lower inner part of the surface is the triangular area of insertion of the semimembranosus.

The lower part of the shaft gradually increases in width and passes without a sharp line of demarcation into the lower extremity. The flattened area above the condyles forms the **popliteal space**.

The **Lower Extremity** is widest below and behind, and its greatest transverse diameter is twice as great as the transverse diameter of the shaft. Its anterior surface is on the same plane as the anterior surface of the shaft, but its posterior surface is prolonged backward. It appears to be directed slightly inward, away from the long axis of the shaft, but this is due more to the obliquity of the lines upon the extremity than to the obliquity of the extremity itself. The lower extremity consists of two condyles, separated in front and below by the shallow trochlear surface for the patella, and below and behind by the deep intercondyloid notch. The condyles have in general the same shape, and differ only slightly in detail.

The **external condyle** is longer and wider than the internal. When viewed from the side (Fig. 530) the anterior border is seen to leave the straight line of the anterior surface of the shaft, and, curving downward and backward, to form an arc of a large circle the centre of which lies on the external border near the junction of the shaft with the lower extremity. This curve is continued until the lower point of the condyle is reached, beyond which the curve alters, and, as a posterior border of the condyle, describes the half of a circle whereof the centre is at the most prominent point of the side. The curve ends abruptly, and the upper part of the posterior border passes upward and forward into the external border of the shaft as a sharp ridge, known as the **supracondyloid ridge**. About on a level with the

FIG. 532.



LEFT FEMUR, POSTERIOR ASPECT.

point at which the anterior border of the condyle leaves the straight line is the top of the trochlea.

The upper anterior part of the condyle is smooth and concave from before backward, and separated from the trochlea in front by a distinct crest. The lower posterior part is rough and elevated, and its highest point is called the epicondyle or **outer tuberosity**; the border is rounded and passes into the articular surface below. Near the border are **two pits**, whereof the anterior marks the origin of the extensor longus digitorum, and the posterior the origin of the popliteus muscle. Almost at the centre of the tuberosity is a circular, **flattened space** for the insertion of the external lateral ligament of the knee-joint. Above this space, just at the beginning of the supracondyloid ridge, is a well-marked **oval depression** where the outer head of the gastrocnemius muscle arises.

The part of the condyle seen on the posterior aspect (Fig. 532) and included between the roughened lower part of the outer surface and the notch which separates it from the other condyle is occupied by the **articular surface**. This surface begins at the distal end of the external half of the trochlea, curves slightly outward and downward, then backward and upward, and then forward. A ridge more or less plainly marked and running from without obliquely backward and inward separates the trochlea from the articular surface. Its arcuate outer border is the lower and posterior border already described; its inner emarginate border forms the outer margin of the intercondyloid notch and is nearly parallel with the outer border; both of these borders are directed outward and backward.

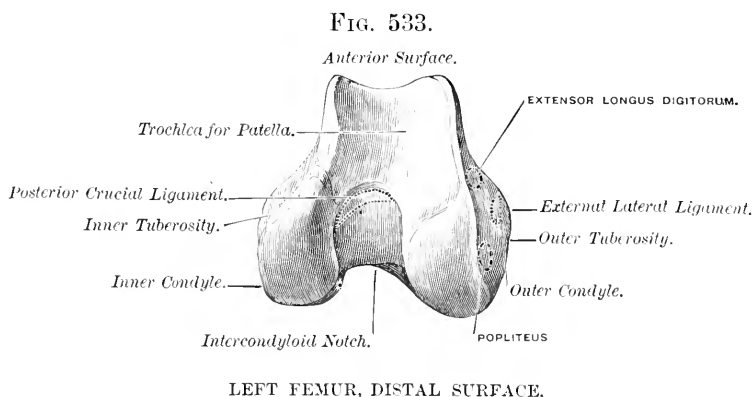
The articular surface is, of course, strongly convex from above downward and convex from side to side; the greater part of the convexity faces inward and backward. It slopes from the outer edge toward the intercondyloid notch. At the superior part of the surface is a flat, smooth space whereon the sesamoid bone in the tendon of the outer head of the gastrocnemius muscle glides.

The **inner condyle** is not so wide transversely as the outer, and its tuberosity is not so distinctly marked. On its inner or tibial surface (Fig. 531) the **depression** above the posterior termination of the articular surface, for the attachment of the tendon of the inner head of the gastrocnemius muscle, is shallower and smaller than the corresponding depression on the external condyle. The inner supracondyloid ridge

is more prominent than the outer ridge, and the external lateral ligament is inserted into a distinct pit on the tuberosity behind the centre.

The **articular surface** on the distal and posterior side of the condyle (Figs. 532, 533) is narrower than the outer surface, and begins without a distinct line of separation at the lower part of the trochlea. It is directed at first inward as well as backward; it then becomes wider, and, with almost parallel borders, curves upward and outward. It is more evenly convex than the external articular surface, and does not face so much toward the intercondyloid notch.

The **trochlea** (Fig. 533) is a linear, grooved, articular surface continuous with the anterior surface of the shaft of the femur; it arches

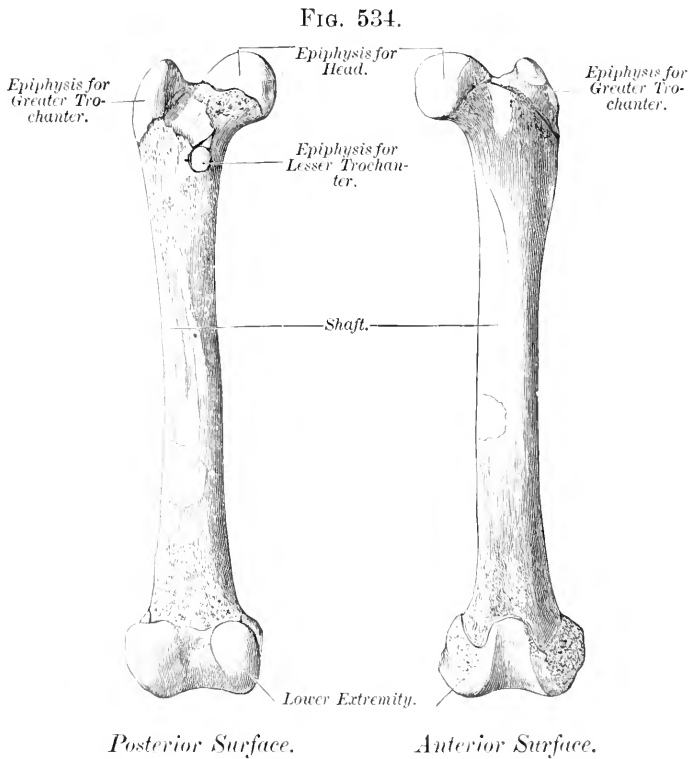


downward and backward, passes at the sides, without distinct limitation, into the articular surfaces on the outer and inner condyles, and ends abruptly in the middle line at the front part of the intercondyloid notch. Its upper margin is arcuate; the outer end of the curve is slightly higher than the inner end. The lateral borders are prominent, straight, and parallel. The articular surface of the trochlea is about twice as long as wide, strongly convex from above downward, and concave from side to side. It articulates with the posterior surface of the patella.

The **intercondyloid notch** (Figs. 532, 533) lies at the lower and posterior part of the lower extremity of the femur, between the condyles. It is more than twice as long as it is wide, sharply limited in front from the trochlea and at the sides from the condyles; above, it is separated by a transverse ridge from the lower part of the popliteal space.

It is concave from side to side and convex from above downward.

Its surface is marked by a number of foramina for the transmission of vessels to the cancellated tissue of the extremity and by three distinct depressions for the attachment of ligaments. The **anterior depression** lies just posterior to the entire front margin and the anterior end of the internal lateral margin. It is semilunar in shape, with the convexity pointing forward and inward. It lodges the upper end of the posterior crucial ligament of the knee-joint. The two other depressions lie at the superior part of the notch, one on each side, close to the articular surface. The **external depression** is oval and is the larger, and marks one end of attachment of the anterior crucial ligament; the **internal depression** is circular and smaller, and affords attachment to the external semilunar cartilage.



PLAN OF THE DEVELOPMENT OF THE FEMUR BY FIVE CENTRES.

**Nomenclature.**—Femur is the Latin for the thigh, but is now used for the bone of the thigh, which, strictly speaking, should be termed *os femoris*. *Os coxae* has been employed for the femur. The German term is *das Oberschenkelbein*, the French, *le fémur*.

**Determination.**—If the femur be held vertically, with the head

above and the anterior surface toward the student, the head will be on the side to which the bone belongs.

**Articulation.**—The femur articulates with the innominate, the tibia, and the patella.

**Muscular Attachments.**—The following muscles are attached to the femur :

To the greater trochanter, the *gluteus medius*, the *pyriformis*, the *gluteus minimus*, the *obturator internus*, the *obturator externus*, the *gemelli*, the *gluteus maximus*, and the *quadratus femoris*.

To the lesser trochanter, the *psoas* and the *iliacus*.

To the shaft, the *gluteus quartus*, the *gluteus maximus*, the *quadriceps extensor* (formed of the *vastus externus*, the *vastus internus*, and the *crureus*), the *tensor vaginæ femoris*, the *pectineus*, the *adductor*, and the *semimembranosus*.

To both condyles, the *gastrocnemius*.

To the outer condyle, the *popliteus* and the *extensor longus digitorum*.

**Blood-Supply.**—The shaft of the femur is pierced by the nutrient artery arising from the femoral artery.

**Ossification.**—The femur is developed from five centres : one for the shaft, one for the head, one for the lower extremity, one for the greater trochanter, and one for the lesser trochanter (Fig. 534).

In some specimens examined, the lower extremity appeared to ossify from two distinct centres, one for each condyle.

#### VARIATIONS IN THE FEMUR.

##### VARIATIONS IN SIZE.

The measurements of the femur are taken as follows :

The maximum length is the distance from a median point on a line drawn transversely to the top of the head or the greater trochanter, whichever is highest when the bone is held vertically, to the lowest point on the articular surface for the tibia.

The width of the upper extremity is the greatest transverse diameter from the convexity of the head to the outer edge of the greater trochanter.

The width at the condyles is the greatest transverse diameter between the prominences of the condyles.

Side.	Maximum length.	Width of upper extremity.	Width at condyles.	Side.	Maximum length.	Width of upper extremity.	Width at condyles.
Left . . . .	90.5	18	16	Left . . . .	100	21	18
Left . . . .	91	18	16	Right . . . .	101	20	18
Right . . . .	91	18	17	Left . . . .	101.5	20	17.5
Left . . . .	91.5	18	16	Left . . . .	102	20	18
Right . . . .	91.5	18.5	16	Right . . . .	102.5	21	18
Right . . . .	91.5	19.5	17.5	Right . . . .	103	20	18.5
Right . . . .	92	18	17	Right . . . .	103	21	18
Left . . . .	92	18.5	17	Left . . . .	104	19	19.5
Right . . . .	92	19	16	Left . . . .	104	20	18
Left . . . .	92	19	16.5	Right . . . .	104	20.5	19
Left . . . .	92	19	17	Right . . . .	104	21	18.5
Right . . . .	93	19	18	Left . . . .	104	21	19
Left . . . .	93	19.5	18	Right . . . .	104	19	19
Left . . . .	94	19	19	Right . . . .	105	21	18.5
Left . . . .	94	21	18	Left . . . .	105	22.5	20
Left . . . .	95	18	17	Left . . . .	105.5	20	19
Left . . . .	95	19	17	Left . . . .	106	22	20
Right . . . .	95	19	17	Left . . . .	107	22	20
Left . . . .	95	21	19	Right . . . .	107	22	20
Right . . . .	95	21	19.5	Right . . . .	109	22	21
Left . . . .	96	19	18	Left . . . .	109.5	22	21
Left . . . .	96	20	18.5	Right . . . .	110	23	21
Right . . . .	96	20	20	Left . . . .	111	23	19.5
Right . . . .	97	18	17	Left . . . .	111	23	20
Left . . . .	97	19	17	Right . . . .	111.5	23	20
Right . . . .	97	20	19	Left . . . .	113.5	21.5	20
Left . . . .	97.5	20	18	Left . . . .	114	23	20
Left . . . .	98	19.5	18	Left . . . .	115	22	20
Left . . . .	98	20	18	Left . . . .	115	22.5	21.5
Left . . . .	98.5	19	17	Right . . . .	115	23	21
Right . . . .	98.5	20	18	Left . . . .	116	23	20
Right . . . .	98.5	20	19	Right . . . .	116	23	21
Right . . . .	99	19	17.5	Right . . . .	116.5	24	21
Left . . . .	99	19.5	17	Right . . . .	117	23	20
Left . . . .	99	19.5	18	Left . . . .	117	23.5	20
Right . . . .	100	19.5	18	Left . . . .	117	24	21
Right . . . .	100	20	19				

## VARIATIONS IN FORM AND DEVELOPMENT.

The femur exhibits such general changes as are dependent merely upon the relative increase or decrease of its diameters; hence we find long and narrow femora, short and broad femora, and femora with more or less prominent extremities. The lateral angle which the head and neck make with the shaft varies between one hundred and twenty and one hundred and twenty-five degrees; it appears to vary more because the trochanter is sometimes above the level of the head and sometimes below it. The upper margin of the neck may be straight or deeply incised. The forward angle of the head and shaft is also slightly variable. The lesser trochanter is occasionally inconspicuous; in

some specimens it is abnormally large and hooked. Inasmuch as the distance from the head to the edge of the greater trochanter is variable, the **digital fossa** varies in width; it also varies in depth and in the extent to which it is overhung by the edge of the trochanter. The articular surface on the head is sometimes separated from the digital fossa by a well-marked **tubercle**. The pit on the head for the **ligamentum teres** is occasionally obscure; it is usually marked by two parallel deeper cuts.

The **greater trochanter** varies in antero-posterior width and in the clearness of the markings on its outer surface. A **foramen** is often present between the head and the lesser trochanter, above the anterior intertrochanteric line.

The **shaft** appears to be constantly straight, and exhibits only slight variations in its curvature. In one specimen the superior end of the **internal border**, below the anterior intertrochanteric line, presented a well-marked swelling for the upper end of the **vastus internus**.

The **linea aspera** varies in development. In one specimen examined it was very high, especially the inner branch limiting the **vastus internus** muscle. In another specimen the lower part of the outer branch and all of the common trunk was drawn inward and backward into an irregular sheet six millimetres wide and twenty-eight millimetres long, to which was fastened the adductor muscle.

The **external border** may be indistinct throughout; its upper part is not infrequently developed into a decided crest. The anterior surface of the **trochlea** varies in width and in degree of concavity. In some specimens its inner border is shorter and more arcuate, in others both borders appear to be equal. The width, depth, and degree of obliquity of the **intercondyloid notch** are subject to slight variations.

### HUMAN FEMUR.

The femur in man (Fig. 535) is the longest and strongest bone in the skeleton. In the cat it ranks in length below the tibia and the ulna. The shaft of the human bone is also relatively more slender than in the cat; it is cylindrical, and bowed more strongly forward.

The **head** forms about five-tenths of a sphere, and is separated from the rest of the upper extremity by a longer and more clearly defined neck, on the posterior part whereof the articular surface does not encroach. Owing to the greater length of the neck and the lesser



size of the greater trochanter, the neck appears to join the shaft at a greater angle than does the neck of the cat's femur, but there is, in fact, little difference, the angle measuring from one hundred and twenty-five to one hundred and thirty degrees.

The **greater trochanter** is more quadrate, and its inner posterior edge does not overhang to so marked a degree the digital fossa for the obturator externus muscle. The outer surface is crossed by an oblique line which passes from behind and above forward and downward and receives the gluteus medius muscle. The rough space in front of the line is for the insertion of the gluteus minimus. On the upper edge of the trochanter are inserted the obturator internus, gemelli, and piriformis muscles.

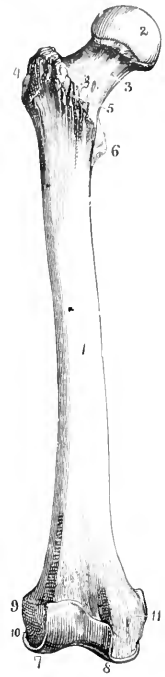
The **posterior intertrochanteric line** is well marked. At a point near the middle of its length is a distinct tubercle, from which a line is continued downward to the linea aspera; to the tubercle and the line is attached the quadratus femoris muscle.

The **lesser trochanter** is prominent, and receives the attachment of the psoas muscle.

The **anterior intertrochanteric line** begins in a **superior cervical tubercle** at the front of the greater trochanter, and ends in an **inferior cervical tubercle** on a level with the lesser trochanter; at this point the **spiral line** of the linea aspera begins. To the cervical tubercles are attached the limbs of the Y ligament of the hip-joint.

The **shaft** presents three borders, limiting three surfaces. Of the borders, the posterior is much more distinct, and is known as the **linea aspera** of the femur. At the middle of its course it presents two lips and an intervening space; below, the lips separate to join the supracondyloid ridges, and the intervening space becomes continuous with the flattened popliteal space. The upper part of the inner lip winds upward and inward, and becomes the spiral line; the upper part of the outer lip joins a long, roughened space, sometimes called the

FIG. 535.



RIGHT FEMUR. FRONT VIEW.

1, the shaft; 2, head; 3, neck; 4, greater trochanter; 5, anterior intertrochanteric ridge; 6, lesser trochanter; 7, external condyle; 8, internal condyle; 9, external epicondyle; 10, groove for the popliteal tendon; 11, internal epicondyle.

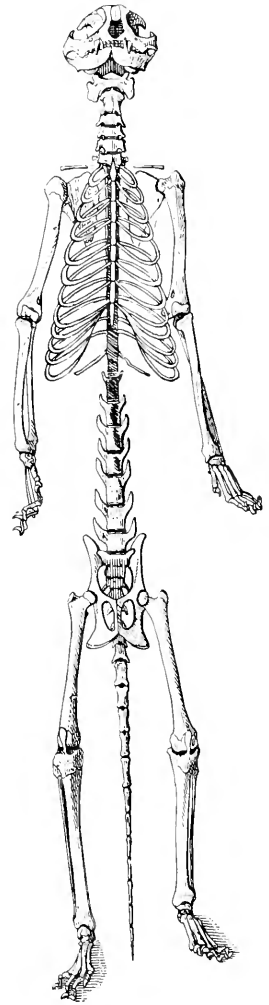
gluteal tuberosity, and ends at the greater trochanter. The inner lip, before it winds forward as the spiral line, sends a ridge upward to the lesser trochanter. To this ridge is attached the pectineus muscle, and between it and the spiral line the iliacus. The upper part of the intervening space is connected by a ridge with the tubercle and line for the quadratus femoris muscle. To the entire length of the inner

FIG. 536.



THE HUMAN SKELETON.

FIG. 537.



THE SKELETON OF THE CAT.

lip is attached the vastus internus muscle, and to its lower half the adductor magnus. To the entire length of the outer lip is fastened the vastus externus, to its upper half the gluteus maximus and adductor magnus, and to its lower two-thirds the biceps. On the intervening space are inserted the adductores longus and brevis.

The external and internal borders of the shaft are not distinct, but are rather lines of maximum convexity. The internal border separates the areas of the crureus and vastus internus muscles. The anterior surface is the broadest, and for its upper two-thirds affords an area of origin for the crureus muscle, which arises also on the narrower external surface. The internal surface is covered by the vastus internus muscle. The popliteal space is situated between the lower diverging lips of the linea aspera; its inner lip is rounded where it is crossed by the femoral artery.

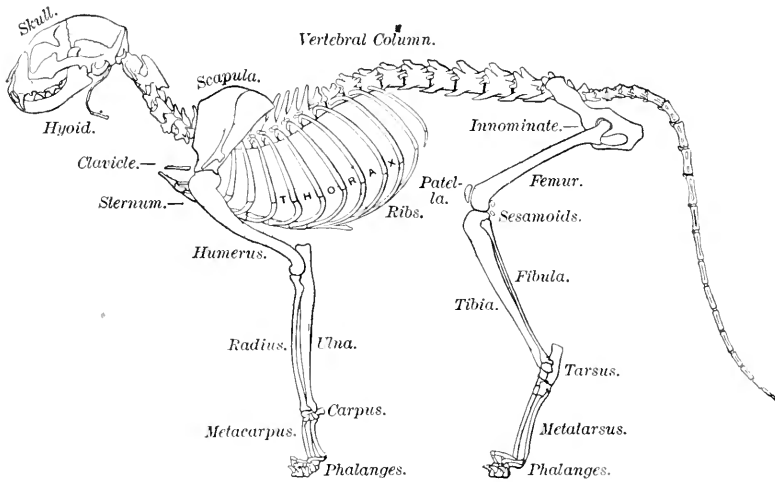
In the lower extremity, the inner condyle is much longer than the outer condyle, and, when the bone is held vertical, projects further downward. In the natural position in the body, however, the femur is directed downward and inward; this brings the two condyles level. The lower ends of the two femora are therefore nearer together than the upper ends; in other words, the knee-joints are closer than the hip-joints (Fig. 536). This is necessary in walking in the upright posture in order that the weight of the body may be brought at each step as near as possible to the line of the centre of gravity. In an animal walking with all four limbs this obliquity of the femora is not required (Fig. 537). Compared with the inner condyle, the outer condyle is more prominent in front, and has greater vertical and antero-posterior diameters. Below the flattened epicondyle are a fossa and a groove for the tendon of the popliteus muscle. The inner epicondyle is larger, and bears a well-marked supracondyloid spur for the tendon of the adductor magnus muscle. The inner ridge of the trochlea is higher than the outer ridge.

#### THE PATELLA.

**General Description.**—The Patella is a small, flat bone which lies in front of the knee-joint (Fig. 538). It is a sesamoid bone developed in the tendon of the quadriceps extensor muscle, which arises on the pelvis and femur and, passing in front of the knee-joint, is inserted into the upper end of the tibia. It affords protection to the joint, and increases the leverage of the great extensor muscle of the leg by keeping its terminal tendon as far as possible in front of the joint.

It resembles in shape and size a small almond (Fig. 539). The blunt end is above and the pointed end is below. It is not quite twice as long as wide, and is compressed from before backward, so that its

FIG. 538.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

greatest antero-posterior diameter is about half as great as the greatest transverse diameter. Its thickest and widest part is a little below

FIG. 539.



LEFT PATELLA, ANTERIOR SURFACE.

the upper end. It has an anterior and a posterior surface, one upper and two lateral borders, and a lower angle.

The anterior surface is bounded by an arcuate, transverse superior margin and more gradually arcuate lateral margins, which are directed downward and inward to meet at the lower angle of the two lateral borders; of these two borders the external is the straighter.

From above downward the anterior surface is strongly convex, and its upper part, which arches backward and upward to the superior border, is slightly convex in the middle and flat or concave below. From side to side it is gently convex, except at the upper extremity, where it is more decidedly arched. This upper part, which comprises about a fifth of the whole surface, is rough and receives the insertion of most of the fibres of the tendon of the quadriceps extensor. The flatter middle part of the surface is almost subcutaneous, and gives attachment to the upper fibres of the part of the tendon which joins the patella to the tibia. This tendon, known as the ligamentum patellæ, arises mainly from the lower part of the anterior surface, which is roughened, and from the lower angle, which is slightly upturned.

The **superior border** is a narrow convex strip, sharply defined from the posterior surface, but almost continuous with the prominent upper part of the anterior surface. At each end it forms rounded acute angles with the lateral borders.

The **lateral borders** are wider than the superior border, and are best defined as forming the lateral margins of the posterior surface.

The **posterior surface** has the same outline as the anterior surface. Except a small area at the tip and along the lower part of the lateral margins, the entire surface is occupied by an articular facet which glides upon the trochlea of the femur. To conform to this groove, the surface is concave from above downward and convex from side to side. The highest transverse convexity is along a longitudinal line which lies nearer the outer than the inner border and divides the surface into an outer smaller and an inner larger, flatter portion. The posterior surface is covered by a layer of cartilage and gives attachment around its borders to the synovial membrane of the joint.

**Nomenclature.**—The word *patella* was introduced into anatomy by Celsus. It was used by the Romans for a flat pan, and is derived from *pātere*, to stand or lie open. The same idea is found in our common word knee-pan. A synonym is *rotula*, a small wheel, which was employed in the Middle Ages either because of the movements of the patella in front of the joint, or because it was round like a wheel. It is perpetuated in the French *la rotule*. The German has *die Kniescheibe*, a translation of an old term, *discus genu*.

**Articulation.**—The patella is attached by ligament to the femur and tibia, and moves in the trochlea of the femur.

**Ossification.**—The patella develops from a single centre of ossification.

#### HUMAN PATELLA.

The transverse diameter of the human patella (Fig. 540) is slightly greater than the vertical diameter; hence the bone is relatively broader and shorter than the corresponding bone of the cat. It is triangular in outline; the apex of the triangle is inferior, the base is superior. It presents anterior and posterior surfaces and superior, external, and internal borders.

The **superior border** is very wide, and might be said to be the upper part of the anterior surface, from which it is separated by a transverse line. It is sharply defined by an arcuate margin from the

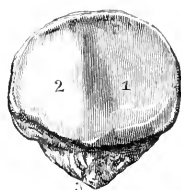
posterior surface. In the border is inserted part of the tendon of the quadriceps extensor muscle.

The external and internal borders are rounded, and afford attachment to the external and internal parts of the quadriceps muscle.

The anterior surface is gently convex, vertically striated, and marked by venous foramina; it is covered with an expansion of the quadriceps tendon, and separated from the skin only by a sac filled with fluid, a so-called bursa. At the apex is fastened the ligamentum patellæ.

The posterior surface (Fig. 540) is mainly occupied by a large, transversely oval articular surface, covered in the recent state with

FIG. 540.



RIGHT PATELLA, POSTERIOR VIEW.

1, 2, articular facet for the trochlea of the femur; 3, apex of the bone roughened for the attachment of its ligament.

a layer of articular cartilage. Below this surface is a triangular roughened area for the attachment of the ligamentum patellæ. The articular surface is divided by a line of maximum convexity into two facets, whereof the external is larger and more deeply concave, and glides on the external condyle of the femur, and the internal is smaller, flatter, and glides on the internal condyle. Both facets are crossed transversely not far from the upper and lower borders

by two faint lines, and the internal facet exhibits, in addition, along the internal border a narrow, more concave area. In this way the articular surface may be said to present seven facets, which, in the different motions of the knee-joint, are applied to the condyles as follows: the two narrow upper facets touch the condyles only in extreme flexion of the leg on the thigh, the larger middle facets in partial flexion, and the smaller lower facets in extension, when the leg is perfectly straight; the vertical internal seventh facet glides on the internal condyle in all positions of the leg.

#### ADDITIONAL SESAMOID BONES.

Three other sesamoid bones stand in relation to the back of the knee-joint.

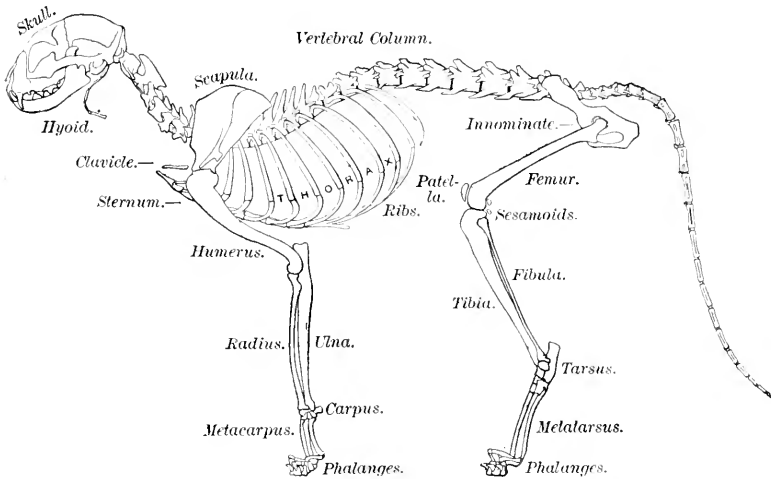
Two of these are found in the tendons of the gastrocnemius muscle, one on each side close to its origin on the supracondyloid ridge just above the condyle. These sesamoids are about the size of the unciform of the wrist, but have the form of an irregular cone so placed that the

pointed end is directed upward. They are everywhere rough for tendinous attachment, except at the part presenting a smooth, rounded facet applied to the smooth space at the upper posterior part of the articular surface of the femoral condyle.

The third sesamoid is at the outer side of the joint, in the tendon of the popliteus muscle, near its origin on the outer condyle of the femur. It resembles a small patella, but is more nearly round. Its outer surface is convex, the line of maximum convexity crossing the surface obliquely. The inner surface is transversely faintly convex and definitely concave from end to end, thus conforming to the rounded posterior part of the outer condyle of the tibia, on which it moves.

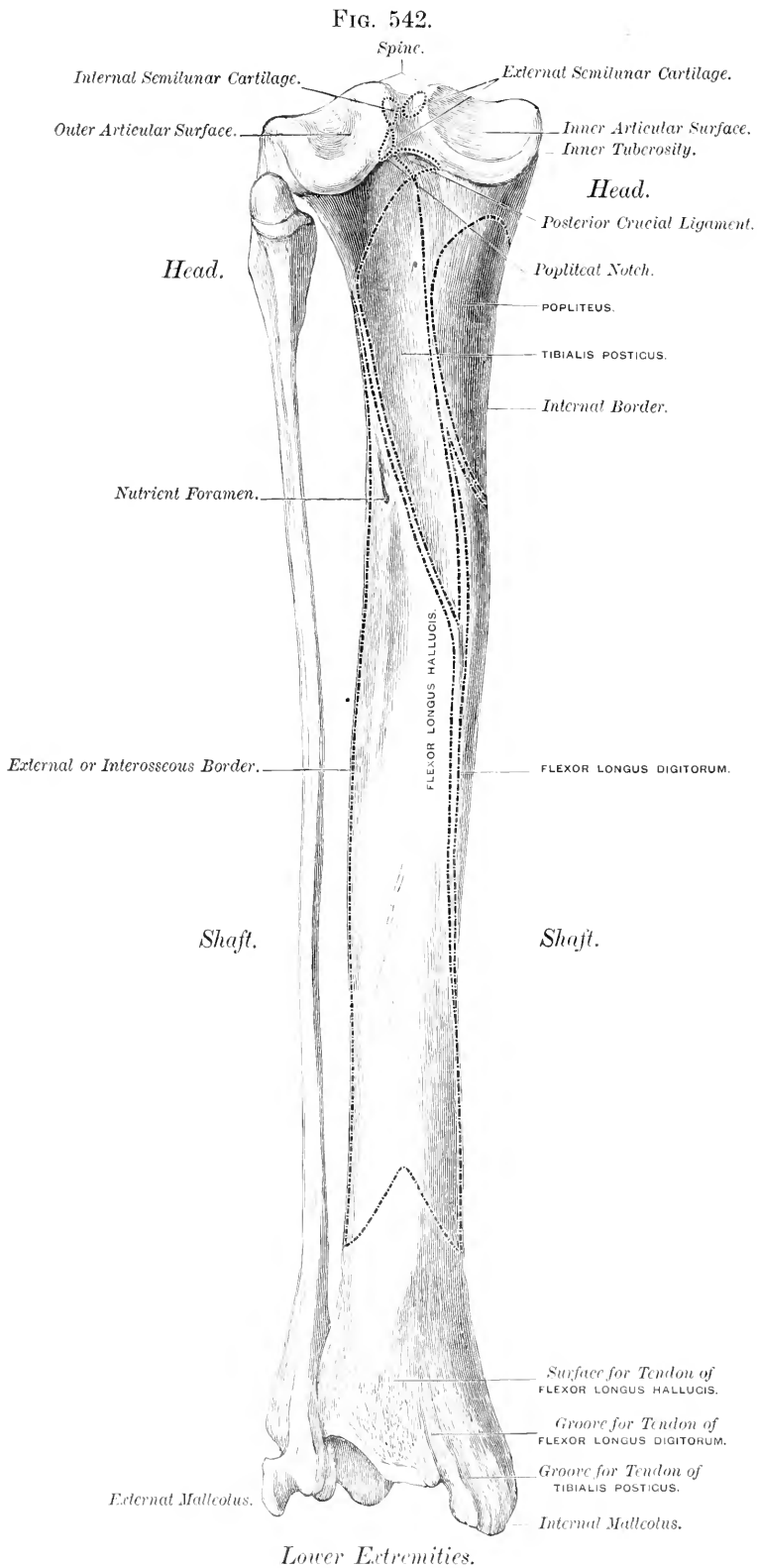
### THE TIBIA.

FIG. 541.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

**General Description.**—Of the two bones of the leg, the inner one, or the Tibia, is the longer and stronger, and is the longest bone in the skeleton (Fig. 541); its broad upper end articulates with the femur at the knee-joint, and its lower end articulates at the ankle-joint with the ankle bone, the astragalus. Inasmuch as the other bone of the leg, the fibula, does not articulate with the femur above, and, though forming part of the ankle-joint, is applied merely to the outer side of the astragalus, the tibia is by far the more important bone of the leg. It is nearly straight, heavy and prismatic above, more slender and rounded below. The front part is subcutaneous, but not so immediately under the skin as is the human tibia, because of the downward



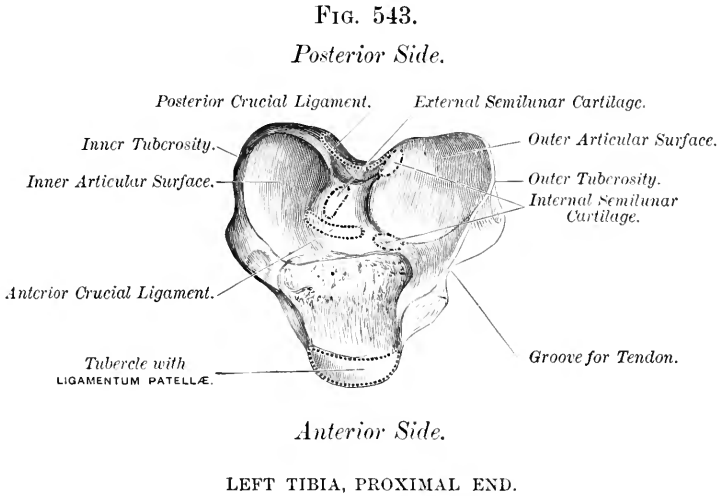
BONES OF THE LEFT LEG. POSTERIOR ASPECT.



extension of the aponeurosis of the biceps femoris muscle. The tibia has an upper extremity or head, a shaft, and a lower extremity.

The **Head** is expanded from before backward and from side to side, and each lateral mass is termed a **tuberosity**.

The **superior** or **proximal surface** (Fig. 543) of the head is triangular; the apex of the triangle is directed to the front and slightly



outward; the base, which nearly equals in length the two sides, faces backward and somewhat inward. The triangular surface is divided by a transverse depression into an anterior and a posterior half.

The greater part of the anterior half is rough for ligamentous attachment, and is pierced by numerous foramina for vessels. Its well-defined lateral margins are distinctly emarginate, and the anterior angle is transversely truncate. It is flat behind, and then gently convex from behind forward; it finally becomes more smooth, and arches boldly downward to a transverse swelling of the upper end of the anterior border of the bone, known as the **tubercle** of the tibia.

The posterior half of the upper surface of the head is occupied by the smooth outer and inner articular surfaces of the tuberosities and the median antero-posterior groove which separates them. Its lateral margins are gently arcuate; the posterior margin is deeply incised in the middle line by the **popliteal notch**.

The **outer articular surface** is larger than the inner surface. It is ovoid in outline, with the long axis directed from in front backward and outward. From side to side it is gently concave, and from before backward it is strongly arcuate. It is inclined from in front

and within downward, backward, and outward, and therefore when the bone is held vertically it faces upward, backward, and outward. Its **outer border** is the longest, and is slightly arcuate. Its **anterior border** is the shortest; it is straight and directed inward and backward. Just in front of the antero-internal angle is a **pit**, more or less well marked, into which is inserted one end of the internal semilunar cartilage. The **inner border** is arcuate, and prominent, especially behind the middle, where a decided swelling forms one-half of the so-called **spine** of the tibia. On the inner surface of this swelling, and in the groove itself, is inserted the other end of the internal semilunar cartilage. The **posterior border** is slightly arcuate and rounded; it forms the overhanging upper edge of the posterior surface of the head. The postero-external angle is prominent and is directed outward, backward, and downward; it bears a more flattened surface, which articulates with the sesamoid in the tendon of the popliteus muscle. In the groove and on the inner border, behind the insertion of the internal semilunar cartilage, is inserted one end of the external semilunar cartilage.

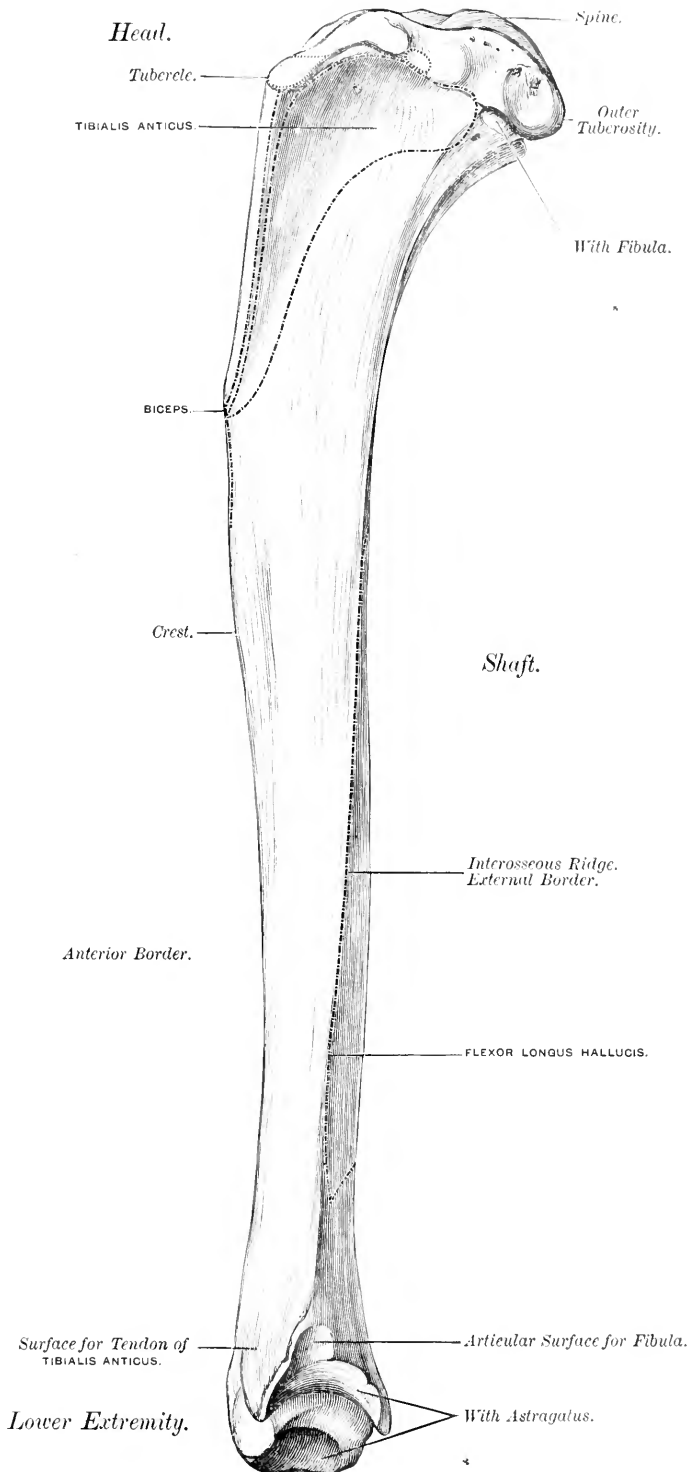
The **inner articular surface** is narrower transversely than the outer articular surface. Its outline is oval, and the long axis is directed antero-posteriorly. The lateral and median margins are slightly arcuate; the latter is interrupted by a swelling which forms the other half of the tibial spine and affords attachment to the outer end of the external semilunar cartilage. The articular surface does not cover the entire inner posterior half of the upper surface of the bone, but leaves a strip along the posterior margin for the insertion of the posterior crucial ligament. The tibial end of the anterior crucial ligament is attached to the median margin and to the inner articular surface itself just in front of the insertion of the external semilunar cartilage. The surface is slightly concave from side to side and convex from before backward.

The groove which separates the two articular surfaces is narrowed in the middle by the approach of the two prominences which together are called the spine. These prominences are not directly opposite each other; the external lies somewhat posterior to the internal.

The articular surfaces are covered by the semilunar fibro-cartilages, which form two well-defined cups in which the condyles of the femur move backward and forward.

FIG. 544.

*Articulates with Femur.*



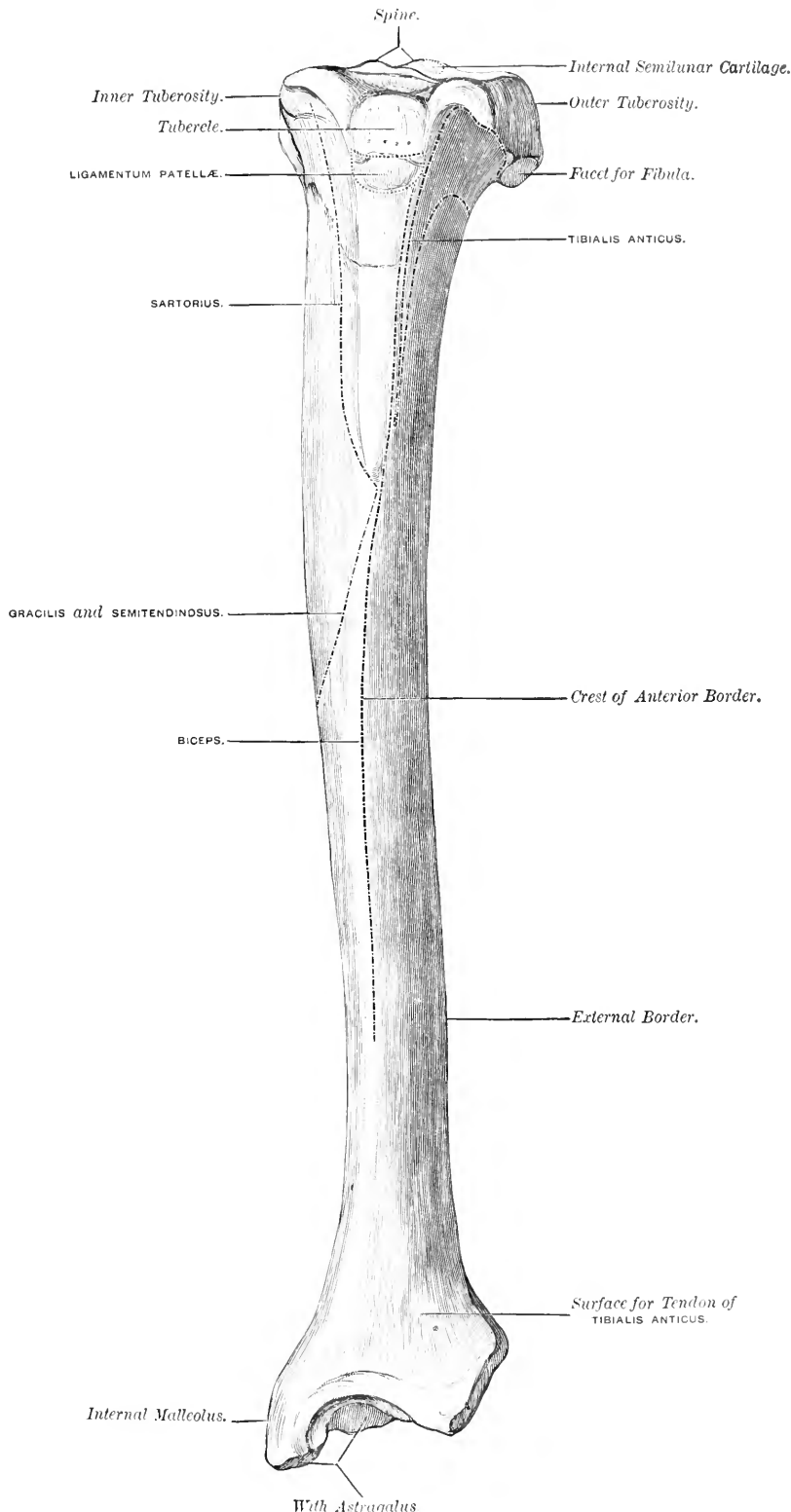
LEFT TIBIA, OUTER ASPECT.

The **external** or **fibular** surface of the outer tuberosity (Fig. 544) is narrow but well defined. Its **upper border**, which is at the same time the outer border of the superior or proximal surface, is regularly arched, and the anterior end extends lower than the posterior, terminating in the side of the tibial tubercle. The **lower border** forms a rounded posterior angle with the upper border, and passes forward and upward to a point near its anterior third, where it is considerably higher than at its origin. It here bends, nearly at a right angle, sharply downward, and joins the superior border at the side of the tubercle. The surface enclosed between these borders consists of two parts, an oval posterior and a narrow anterior part. The long diameter of the posterior part is directed upward and forward, and that of the anterior part downward and forward. The surface is not exactly vertical, but slopes from above outward as well as downward; at its middle is a nearly vertical groove for the tendon of the extensor longus digitorum. The whole surface is rough for the attachment of ligaments.

The external surface of the tuberosity overhangs the external surface of the shaft, and under it, near the posterior angle, is the **oval facet** for the head of the fibula.

The **internal surface** of the inner tuberosity (Fig. 547) differs from the outer surface of the outer tuberosity in being practically in the same plane as the internal surface of the shaft below, from which it cannot be sharply distinguished. There are usually some traces of the suture which separated the epiphysis of the head from the shaft, and this suture may be considered the lower boundary of the surface. The upper margin of the surface is curved, passing from behind forward, at first upward, then forward, and then downward and forward, and finally ending in front at the inner side of the tubercle. Its posterior half is sharp and prominent; the anterior half is rounded. The surface may be said to be curved and to follow the superior border. It is wider behind, where it faces downward and inward, than in front, where it faces upward and inward. It is rough for the attachment of ligaments, especially the capsular ligament of the knee-joint. A shallow **vertical groove** not far from the posterior angle permits the passage of the internal lateral ligament from the femur to the inner side of the shaft. Just behind this groove is the area of insertion of the semimembranosus muscle.

FIG. 545.



LEFT TIBIA, ANTERIOR ASPECT.

The **anterior surface** (Fig. 545) which connects the two tuberosities is the downward prolongation of the superior surface. That portion which is seen when the bone is viewed directly from the front is nearly square; it is bounded above by the general proximal or superior surface, on the sides by the narrow parts of the internal and external surfaces, and below by the upper transverse margin of the tubercle. It is roughened, and faces upward and forward.

The **posterior surface** (Fig. 546) is merely the roughened posterior border of the superior surface. It overhangs the posterior surface of the shaft, and is deeply depressed in the middle by the **popliteal notch**, in which the tibial end of the posterior crucial ligament is fastened.

The **Shaft** is nearly straight, with a curve so faintly sinuous that the upper end is directed slightly outward and the lower end slightly inward. It is also somewhat twisted on its long axis; the front part, therefore, faces also slightly outward above and below. The shaft has three borders, the anterior, the external, and the internal, which limit three surfaces, the external, the internal, and the posterior. These are all clearly marked above, but they are apt to be indefinite below, where the bone becomes more nearly round.

The **anterior border** (Fig. 545) is distinct down to the middle, beyond which it may become obscure. It is subcutaneous, and is called the **crest** of the tibia, or the shin. At its upper end is a flattened rectangular space which is about twice as wide as long and faces upward and forward. It receives the insertion of the ligamentum patellæ, and is called the **tubercle** of the tibia. The beginning of the crest is as wide as the tubercle itself, but it rapidly narrows to a sharp border. Its upper part lies on the outer side of the long axis of the bone, but at the junction of the upper and middle thirds it comes directly to the front, and at the lower third is seen midway between the real anterior line and the internal border. The anterior border affords attachment for almost its entire length to the aponeurotic termination of the biceps femoris. In its upper fourth it limits the anterior margin of the area of origin of the tibialis anticus muscle.

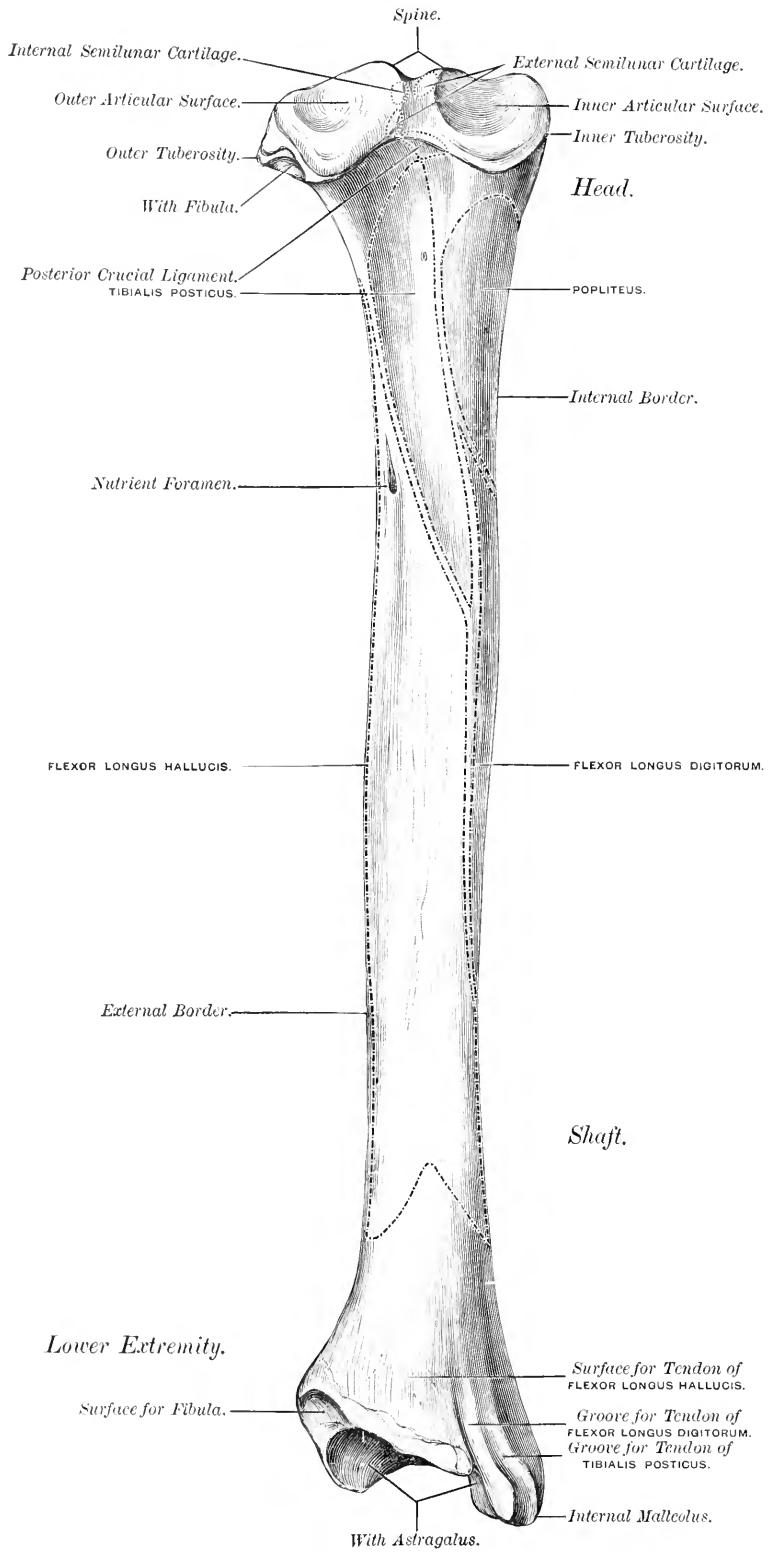
The **external border** (Fig. 544) is always well defined, inasmuch as it is the line of attachment of the strong interosseous membrane which unites the tibia with the fibula, and gives additional area of origin to the anterior and posterior muscles of the leg. It begins at the posterior angle of the outer tuberosity, just behind the articular

facet for the fibula, and passes obliquely downward and forward to occupy the middle line of the outer aspect of the bone in its lower fourth, and to end at the apex of the triangular articular facet for the lower extremity of the fibula. The border is sharp, and defines the outer edge of the tibial area of origin of the flexor longus hallucis muscle.

The internal border (Fig. 547) may be easily mistaken, inasmuch as there is an apparent internal border which limits the inner aspect of the bone, but is not the true internal border, which is the point of division of muscular and aponeurotic attachment. This internal border lies in front of the apparent border, and begins above in the roughened line for the insertion of the internal lateral ligament; it then curves slightly forward, and at the middle of the bone lies exactly in the median line of the inner aspect. From this point it curves backward, and at the lower fourth runs along the posterior edge of this aspect of the bone. The upper end of the internal border affords insertion for the internal lateral ligament. The aponeurosis of the gracilis and semitendinosus is attached from about the middle down to the lower end. In the upper fourth of the bone the border marks the inner edge of the area of insertion of the popliteus muscle, in the middle fourth that of the flexor longus digitorum, and for a short distance in the upper part of the lower fourth that of the flexor longus hallucis.

The posterior surface of the shaft (Fig. 546) is defined by the external and internal borders, and is wider above than below. Its external edge is slightly sinuate, and visible for its entire length when the bone is viewed from behind; but the internal border is on the internal aspect of the bone except near the lower extremity. The posterior surface is sharply separated from the upper extremity by the prominent posterior border of the head; it is continuous below with the posterior surface of the lower extremity. It is divided by a longitudinal ridge—namely, the apparent internal border—into (1) a very narrow internal part and (2) a broad external part. The greater portion of the internal part faces inward, and all of the external part faces directly backward. The ridge begins above, just on the inside of the popliteal or intercondyloid notch, and runs obliquely through the upper fourth nearly to the internal border, where it divides into two branches, whereof one is continued to meet the internal border at a

FIG. 546.



LEFT TIBIA, POSTERIOR SURFACE.



point where the upper third of the bone joins the lower two-thirds. The other branch passes downward to join the true internal border in the lower fifth of the bone.

(1) The internal part of the posterior surface is not only separated from the external part by this arrangement, but is itself divided into (a) an upper and (b) a lower area.

(a) The upper area is about one-third as long as the bone, and is triangular, the apex of the triangle pointing downward and forward. It is transversely strongly convex above, where it faces backward and inward; it is slightly convex below, where it faces inward. It is occupied by the insertion of the popliteus muscle.

(b) The lower area of the inner part of the posterior surface has the shape of a long, narrow spindle, flattened or only slightly convex transversely and facing directly inward. The greater part is occupied by the area of origin of the flexor longus digitorum muscle.

(2) The outer part of the posterior surface has almost parallel lateral borders, but it is slightly narrower above than below. It is also divided into two areas by an oblique line which arises above in the external border of the bone, just under the articular facet for the fibula, and runs downward and inward to join, at the middle of the bone, the outer branch of the longitudinal ridge above described. The upper area is triangular and concave in both directions above, but nearly flat below. It is deeply depressed at its upper inner angle, where are found a number of foramina for blood-vessels; it affords origin through its entire extent to the tibialis posticus muscle. The lower area of this part of the posterior surface is in the form of a long triangle, the apex whereof is at the upper end of the external border. It gives origin to part of the flexor longus hallucis. In its upper part it is nearly flat from side to side and concave from above downward; in the lower part it is convex in both directions. On this surface, at about the junction of the upper third of the bone with the lower two-thirds and midway between the oblique line and the outer border, is the main nutrient foramen of the tibia, which pierces the bone obliquely downward.

The external surface of the shaft (Fig. 544) lies between the anterior and external borders, below the prominent lower edge of the external surface of the outer tuberosity and continuous below with the anterior surface of the lower extremity. For its upper third it occu-

pies the outer aspect of the bone; it then twists to the front and faces forward and outward, until at the lower end it appears as an anterior surface. Its upper part is nearly flat or slightly concave from before backward, concave from above downward, and is overhung above by the external surface of the upper extremity and in front by the prominent everted anterior border or crest. In the angle thus formed is the area of tibial origin of the tibialis anticus muscle. The lower two-thirds of the surface are convex from side to side, and at first convex and then somewhat concave from above downward. No muscle arises from this surface, which is nearly covered by the muscles arising higher up.

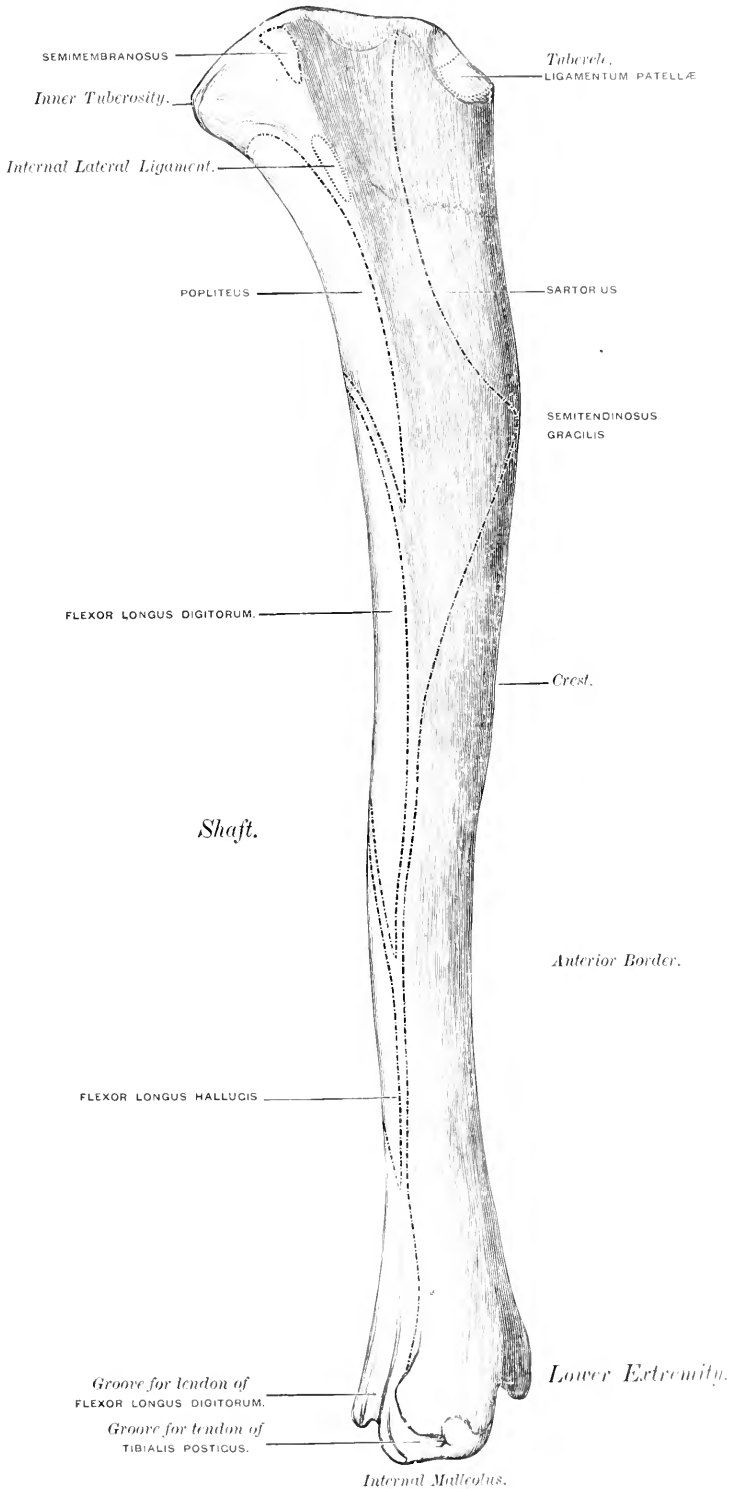
The **internal surface** (Fig. 547) is wholly visible on the inner aspect of the bone. It lies between the anterior and internal borders; there is no sharp line dividing it from the internal surface of the upper extremity, and below it becomes the surface of the internal malleolus. The internal surface is very wide above between the tibial crest and the roughened line on the internal border which marks the insertion of the internal lateral ligament. From this point it narrows until at about the middle of the bone it is not quite one-fourth as wide as it is above. It then gradually widens, and at the lower end is twice as wide as at the middle. At its upper end it is concave from before backward and from above downward; lower down it is nearly flat from before backward and convex from above downward; below the middle it is concave from above downward and convex from before backward. In the upper part it faces forward as well as inward, and in the lower part almost directly inward. There are no extensive areas of muscular origin and insertion on the internal surface. The broad aponeurosis of the sartorius is fastened on a curved line beginning above, near the middle of the surface, and running forward to the most prominent part of the tibial crest, where the upper fourth of the bone joins the lower three-fourths. The aponeurosis of the semitendinosus and the gracilis is inserted on a line which begins above where the sartorius ends, and runs backward and downward to meet the internal border at the middle of the bone. From this point the aponeurosis is blended with the fascia covering the flexor longus digitorum and flexor longus hallucis muscles, and continues down on the internal border nearly to its end.

The **Lower Extremity** is expanded laterally, principally on the

FIG. 547.

*Head.*

*Articulates with Femur.*



LEFT TIBIA, INNER ASPECT

inside. It is scarcely any thicker from before backward than the region of the shaft just above it.

The **internal surface** is continuous above with the internal surface of the shaft, and as this side of the bone is continued broadly down beyond the rest of the lower extremity, to form the prominent projection on the inner side of the ankle-joint known as the **internal malleolus**, the internal surface is much longer than the other surfaces; it is also narrower than the other surfaces. Its **anterior margin** is distinct and nearly straight, but it curves a little backward at the lower end; it represents the lower part of the anterior border of the shaft. The **internal margin** is faint, inasmuch as the internal border of the shaft fades out before it reaches the end. The **lower margin** is nearly straight, with rounded anterior and posterior angles; just in front of the posterior angle, however, is a deep notch which marks the end of a longitudinal groove on the surface.

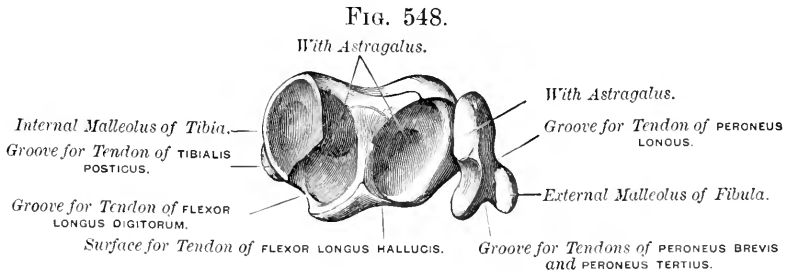
The plane of the internal surface forms a decided angle with the plane of the shaft, and faces upward as well as inward. From before backward it is convex, from above downward it is at first slightly concave, but near the inferior margin it becomes convex. At about one-third the distance from the posterior margin it presents a well-marked longitudinal groove, which begins faintly above near the shaft, runs straight down nearly to the lower margin, and here curves forward. Its lower part is overhung in front by a flat process whereof the posterior arcuate border is connected with the posterior border of the groove by a strong band of connective tissue to form a canal which transmits the tendon of the *tibialis posticus* muscle. Behind this groove, and separated from it by a raised line, more marked at the lower part, is a second longitudinal groove, well defined only near its lower end, and producing a decided notch in the lower margin of the surface. This groove also differs from the other groove in being almost straight. Its posterior margin is the posterior margin of the surface. It also is converted by ligament into a canal for the tendon of the *flexor longus digitorum* muscle. The internal surface is roughened and gives attachment to a part of the internal lateral ligament of the ankle-joint.

The outline of the **posterior surface** is nearly that of a right-angled triangle, the lower border being the hypotenuse, the base an imaginary transverse line separating it from the posterior surface of

the shaft and representing its upper limit, and the other side the internal border. The posterior surface is gently convex transversely, and affords attachment to the posterior ligament of the ankle-joint. The **lower margin** is swollen in the middle, and its internal half is marked by a wide, shallow groove for the tendon of the flexor longus hallucis. The external half, with the part of the posterior surface of the shaft above it, is occupied by a concave triangular articular facet for the lower extremity of the fibula. This facet faces backward and outward.

The **lower or distal surface** (Fig. 548) is divided by a change in the direction of its plane into (1) a smaller internal part and (2) a larger external part.

(1) The internal part is the median surface of the internal malleolus, and faces downward, but principally outward. Its lower margin is arcuate; its upper margin is not well defined; the surface here passes



LEFT TIBIA AND FIBULA, DISTAL ASPECT.

into the external part of the distal surface. About half-way up on the median surface of the malleolus is a line which runs upward and backward to the middle, then bends nearly at a right angle and runs downward and backward. The surface included between the lower border and this line is a segment of a circle, and is slightly concave in both directions; it is rough, and is occupied by a strong ligament attached to the astragalus. Above this bent line the surface is smooth, and articulates with the upper part of the inner surface of the astragalus.

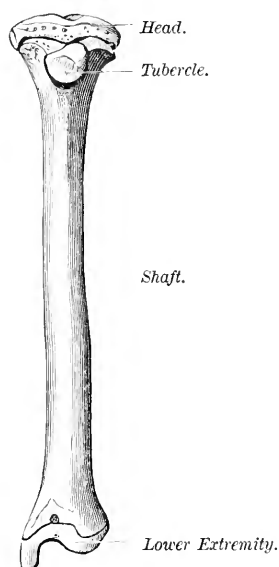
(2) The external part of the distal surface is smooth and covered with articular cartilage. It is divided by a slightly curved ridge into two lateral concave parts, which fit the two convex parts on each side of the median groove on the dorsal surface of the astragalus. The dividing ridge begins in front, at the apex of the triangular anterior surface, and runs obliquely backward and inward to end in the middle

of the groove for the flexor longus hallucis on the lower margin of the posterior surface.

Of the two facets thus separated, the inner is twice as long as it is wide, concave in both directions, and faces almost directly downward. Its long diameter is directed from in front backward and inward, its anterior margin is nearly straight, its posterior end and its inner and outer margins are gently arcuate.

The outer articular facet is wider than the inner, its long axis is more oblique, and its posterior margin is longer. Its outer margin is strongly arcuate, and meets the less arcuate inner margin in anterior

FIG. 549.



PLAN OF THE DEVELOPMENT OF THE TIBIA BY FOUR CENTRES.

and posterior angles. It is concave from before backward and less concave from side to side, and faces as much outward as downward. This surface articulates with the inner side of the outer convexity of the trochlear surface of the astragalus. Inasmuch as the fibula is also applied to the outer side of the astragalus and prevents dislocation of the joint in that direction, this surface of the tibia, just mentioned, does not clasp the outer convexity of the astragalus as the inner surface clasps the inner convexity, where there is no additional bone to prevent lateral dislocation.

**Nomenclature.**—The Latin word *tibia* was used for a wind instrument resembling the clarinet, and, as this instrument was made

of the long bones of animals, the name was transferred to the bone itself. Celsus first employed the term in human anatomy. Tibia was also used for the whole lower leg, the leg-armor being called *tibialia*. Galen called the tibia *cneme*, which is retained in *gastrocnemius*. Because in man it can be felt through the skin, it is called the shin bone, shin being derived from the old German *Schin*, the skin, whence the German word *das Schienbein*. The French is *le tibia*.

**Determination.**—If the tibia be held with the superior extremity upward and the anterior crest toward the student, the malleolus at the lower end will be on the side to which the bone belongs.

**Articulation.**—The tibia articulates with the femur, the patella, the fibula, and the astragalus.

**Muscular Attachments.**—To the outer surface is attached the *tibialis anticus*. To the posterior surface: the *popliteus*, the *tibialis posticus*, the *flexor longus digitorum*, and the *flexor longus hallucis*. To the tubercle: the *ligamentum patellæ*, or tendon of the *quadriceps extensor femoris*. To the anterior border of the shaft: the *biceps femoris*. To the inner tuberosity: the *semimembranosus*. To the internal surface of the shaft: the *sartorius*.

**Blood-Supply.**—The principal blood-supply of the tibia is derived from the nutrient artery of the shaft, which springs from a branch of the popliteal forming the upper part of the *tibialis posticus*, or sometimes from the *tibialis anticus*.

**Ossification.**—The tibia develops from four centres, one for the upper extremity, one for the lower extremity, one for the shaft, and one for the tubercle (Fig. 549).

#### VARIATIONS IN THE TIBIA.

##### VARIATIONS IN SIZE.

The measurements of the tibia are taken as follows:

The maximum length is the distance on the long axis from the highest point on the head to the tip of the malleolus.

The width at the upper end is the greatest transverse diameter between the lateral prominences of the tuberosities.

The width at the lower end is the greatest transverse diameter on a transverse line drawn from the greatest convexity of the malleolus to a point opposite the most projecting point of the fibular articular facet.

Side.	Maximum length.	Width at upper end.	Width at lower end.	Side.	Maximum length.	Width at upper end.	Width at lower end.
Right . . . .	93.5	17	10.5	Right . . . .	105	19	11.5
Right . . . .	94	18	11	Right . . . .	106	18.5	12
Left . . . .	97.5	18	11.5	Left . . . .	106	18.5	12.5
Left . . . .	98	16.5	11	Right . . . .	106	19	12
Right . . . .	98	17	11.5	Right . . . .	106.5	19	12
Left . . . .	98	17	12	Left . . . .	107	19.5	12
Right . . . .	98	18.5	11	Right . . . .	107	20	11
Left . . . .	98.5	17.5	11.5	Left . . . .	108	19	12
Right . . . .	99	18	11	Right . . . .	108	20	13
Left . . . .	99	19	12	Right . . . .	109	18	12
Right . . . .	99	19.5	12	Right . . . .	109	20	12.5
Left . . . .	99.5	17.5	11	Left . . . .	109	20	14
Right . . . .	99.5	19	11	Right . . . .	110	20	13
Right . . . .	100	18	11	Right . . . .	110.5	19	12
Left . . . .	100	18	12	Right . . . .	110.5	21	14
Left . . . .	100	19	11	Right . . . .	111	19	13
Left . . . .	100	19	12	Right . . . .	111	20	13
Left . . . .	100	19	13	Left . . . .	111	21	13
Right . . . .	101	18.5	12	Right . . . .	111.5	20	13
Right . . . .	101	19	11.5	Right . . . .	112	20.5	13
Left . . . .	101	20	12	Left . . . .	114	20	13
Right . . . .	101	20	13.5	Left . . . .	114	21	13.5
Right . . . .	101.5	20	12	Right . . . .	115	20	13
Left . . . .	102	19	11	Left . . . .	115	20.5	13.5
Right . . . .	102	19	12.5	Right . . . .	115	21	13
Left . . . .	102	19	12.5	Right . . . .	116	20.5	14
Right . . . .	102	20	12	Right . . . .	117	21.5	14
Left . . . .	103	17	11	Left . . . .	117.5	21.5	14
Right . . . .	103	18	11.5	Right . . . .	117.5	22	14
Left . . . .	104	18	12	Right . . . .	119	21	13.5
Left . . . .	104	18	12.5	Left . . . .	119	21	14.5
Right . . . .	104	19	11.5	Left . . . .	119	21.5	13.5
Left . . . .	104	19	12	Right . . . .	119	22	13
Right . . . .	104	19	12.5	Right . . . .	119	22	13.5
Left . . . .	104	20	13	Right . . . .	120	21.5	14
Right . . . .	104	21	13.5	Left . . . .	120	22	14
Left . . . .	104.5	18	11	Left . . . .	121	20	14
Right . . . .	104.5	18	12	Left . . . .	122	21.5	14
Right . . . .	104.5	19	12	Right . . . .	122	23	13
Right . . . .	105	18.5	12	Right . . . .	123	21.5	14

## VARIATIONS IN FORM AND DEVELOPMENT.

The tibia exhibits variations in the degree of antero-posterior curvature and in the amount of sigmoid twist from its longitudinal axis. The upper part of the anterior border may be very prominent, or it may be so far reduced that on transverse section that part of the tibia appears more broadly triangular. The upper part of the internal surface, which normally is quite flat, is sometimes decidedly concave from before backward. The area of insertion of the internal lateral ligament may be elevated into a ridge. Not infrequently the external



border is prominent as far down as the articular surface for the fibula. The outer border of the head may lack the groove for the extensor longus digitorum muscle.

### HUMAN TIBIA.

The human tibia (Fig. 550) is shorter than the femur.

Compared with the tibia of the cat, the anterior border of the shaft is sharper but not so prominent in its upper part; hence the antero-posterior diameter of the bone is distinctly reduced.

The external, or interosseous, border is well marked; its upper part is nearer the anterior border than in the cat, therefore the upper part of the external surface is narrower. To the greater part of the external surface is attached the tibialis anticus muscle.

The posterior surface (Fig. 551) is not so deeply concave above as is the corresponding surface of the cat's tibia. It presents the oblique, or popliteal, line passing from the external border downward and inward to the internal border.

FIG. 550.  
LEFT TIBIA AND FIBULA,  
ANTERIOR VIEW.

1, shaft of the tibia; 2, 3, tuberosities; 4, spine; 5, tubercle; 6, crest or shin; 7, lower extremity of the bone; 8, internal malleolus; 9, shaft of the fibula; 10, its head; 11, external malleolus.

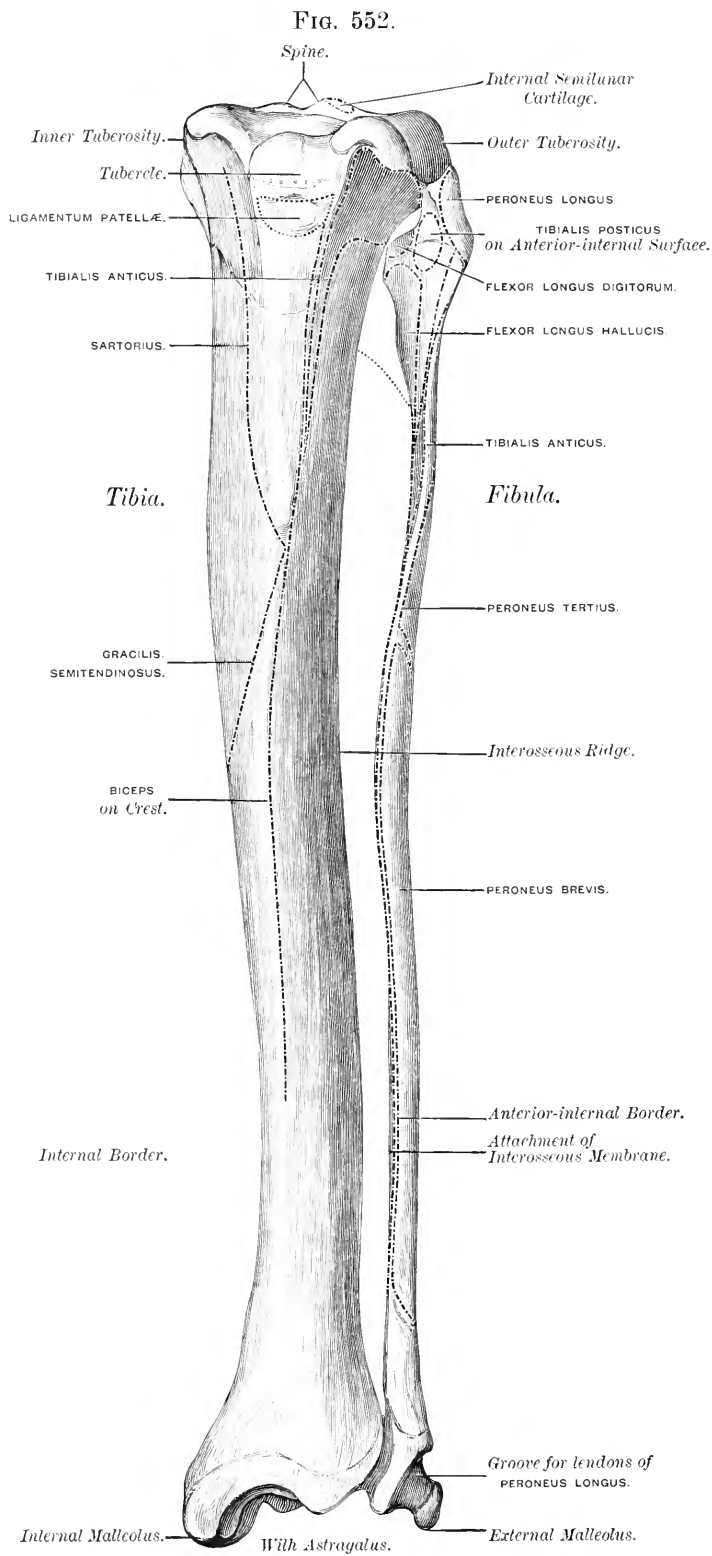
The line affords attachment to the soleus muscle; above the line is inserted the popliteus. The region below the line is divided into two areas by a convex longitudinal line which fades out below on the external border. The external narrower area is for the tibialis posticus; the internal larger area is for the flexor longus digitorum and flexor longus hallucis muscles.

The internal border is well defined, although rounded.

FIG. 551.

RIGHT TIBIA AND FIBULA,  
POSTERIOR VIEW.

1, 2, articular surfaces of the femur for the condyles of the femur, separated by the tibial spine; 3, the inner tuberosity; 4, surface occupied by the popliteal muscle, defined by the popliteal line; 5, 6, nutrient foramen; 7, surface covered by the flexors of the toes; 8, internal malleolus; 9, grooves for tendons; 10, interosseous ridge; 11, head of the fibula; 12, subcutaneous surface at the lower part of the bone; 13, external malleolus; 14, groove for tendons.



LEFT TIBIA AND FIBULA, ANTERIOR ASPECT.

The internal surface is flatter and less undulating from above downward than in the cat. It is free from muscle, and is subcutaneous except near the upper end, where are attached the sartorius, the gracilis, and the semitendinosus.

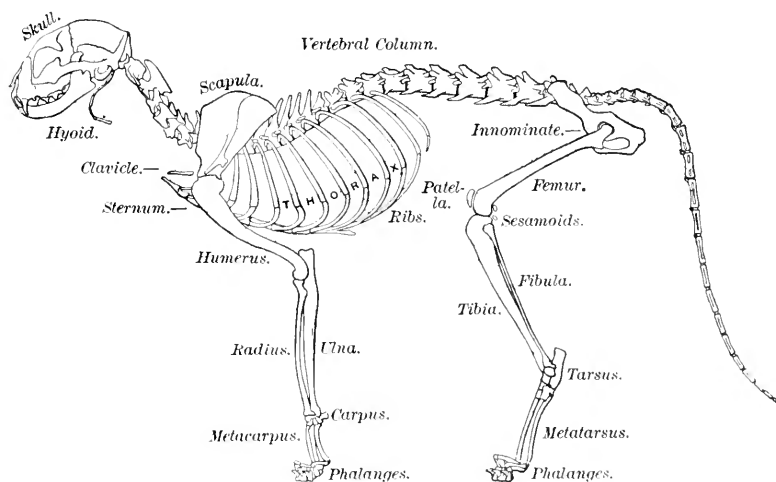
The inferior extremity presents a straight inferior margin, the outer end whereof is not obliquely truncated, but rounded. The surface for the fibula is almost at right angles with the inferior surface, and does not slope upward, outward, and backward. The distal articular surface is flat, because the articular surface of the astragalus is less convex. Of the grooves for tendons, only that on the posterior surface of the malleolus for the tibialis posticus and the flexor longus digitorum is distinctly marked (Fig. 551).

On the superior extremity the tubercle for the patellar tendon is less prominent. The articular surface for the fibula is more posterior. The articular surfaces for the femur are flat and not strongly convex from before backward; they extend to the anterior margin of the head. The spine formed by the two tubercles for the crucial ligaments is more conspicuous.

### THE FIBULA.

**General Description.**—The Fibula is the second bone of the leg. It lies on the outer side, behind the tibia and parallel with it

FIG. 553.



THE SKELETON OF THE CAT. (LEFT SIDE ONLY.)

(Fig. 553). It is embedded in the muscles, and can be felt only at its lower end. It is somewhat shorter than the tibia, as it does not reach

up to the knee-joint. It is very slender, except at the ends, which are flattened and expanded. Its upper end articulates with the outer tuberosity of the tibia; its lower end articulates with the lower end of the tibia and clasps the side of the astragalus. It presents a shaft and two extremities.

The **proximal extremity**, or **Head**, is compressed transversely. When seen from the side it has the form of a pentagon. It is not clearly defined by a neck from the shaft; its surfaces and some of its borders pass into the surfaces and borders of the shaft. It has three surfaces, one on the upper, or proximal, end, and two lateral, which, from their position when the bone is in place in the leg, are called posterior-external and anterior-internal.

The **posterior-external surface** (Fig. 554), as has been said, has the outline of an irregular pentagon, limited by the four borders and an imaginary line drawn transversely to the shaft.

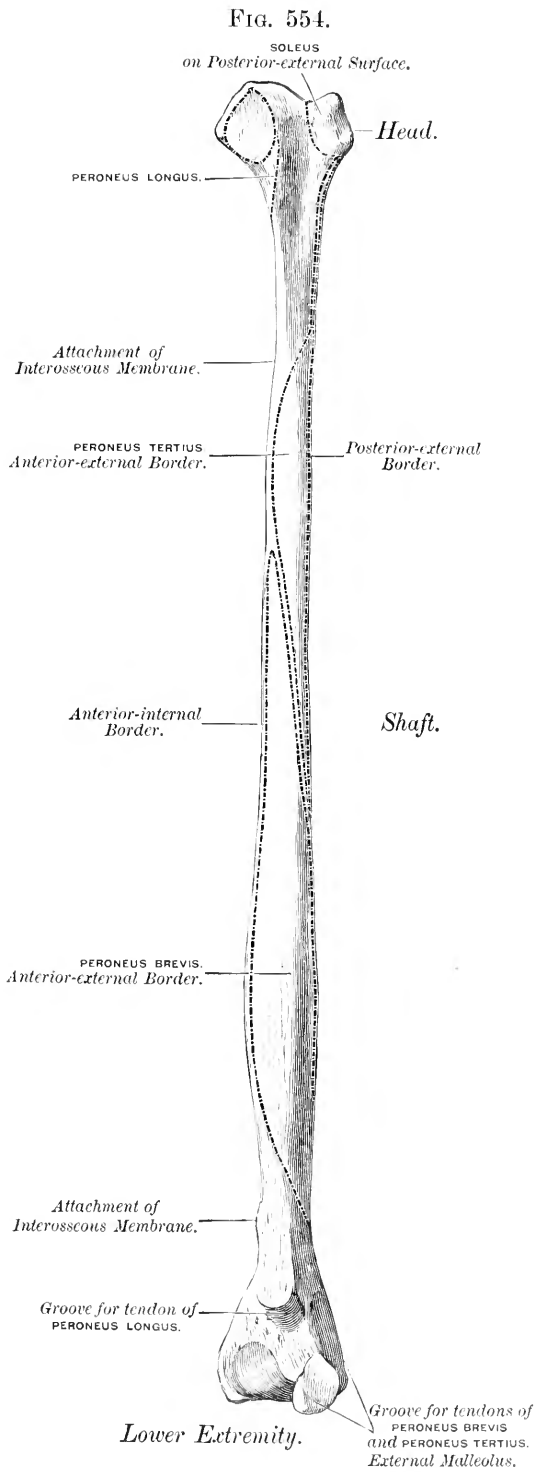
The **anterior-inferior border** is a continuation of the anterior-internal border of the shaft. It is emarginate and directed upward, outward, and forward, forming a right angle with the anterior-superior border above. Its lower part is sharp, but above it is wider and more rounded.

The **anterior-superior border** is directed upward, backward, and inward from the right angle which it makes with the anterior-inferior border; it forms with the superior border an angle somewhat greater than a right angle. This angle is the most proximal point of the entire bone. The border is short, straight, or slightly emarginate; it is rough and rounded.

The **superior border** is the external edge of the proximal surface. It is almost transverse to the long axis of the bone, passing downward a little at its posterior end. It is longer than the other borders, and emarginate, or incised, behind the middle.

The **posterior-superior border** runs downward, backward, and outward from the obtuse angle which it forms above with the superior border, and ends below by joining the posterior-inferior border in another obtuse angle. It is longer than the anterior-superior border but shorter than the proximal border, and is straight but somewhat swollen.

The **posterior-inferior border** is directed downward, inward, and forward into the posterior-external border of the shaft. It is the shortest of the borders, and is emarginate and roughened.



LEFT FIBULA, OUTER ASPECT.

The posterior-external surface presents a median vertical depression limited in front and behind by an eminence. The depression occupies nearly the middle third of the surface. It is narrow above, often not reaching the proximal margin, and wide below, where it passes out on the shaft of the bone; it varies greatly in depth, but is always roughened for the attachment of the tibio-fibular ligament. The anterior eminence is lozenge-shaped, and faces outward, backward, and upward. Its upper part is roughened for the attachment of a tibio-fibular ligament; its lower part presents a smooth facet on which is inserted the external ligament from the femur. The lower part of this facet, with the eminence itself, is embraced by the upper end of the area of origin of the peroneus longus muscle. This eminence is sometimes called the **styloid process** of the fibula. The eminence behind the median depression varies considerably in form, but is usually oblong and convex; its long axis is directed downward and backward, while the eminence as a whole faces outward and backward. It gives attachment by its upper edge to the tibio-fibular ligament and for most of its extent to the tendon of origin of the soleus muscle. From its lower end arises, externally, the posterior-external border of the shaft, and, internally, the posterior-internal border.

The **anterior-internal surface** of the head of the fibula (Fig. 555) has the same outline and the same borders as the posterior-external surface. Its upper margin is bevelled in front and incised behind. Below the articular facet of the proximal surface the surface is rough and gives attachment to the tibio-fibular ligament and the proximal part of the tibialis posticus muscle. The peroneus longus is attached along the anterior-superior border and on the prominent anterior angle, below which arises the upper part of the tibialis anticus. The posterior half of the surface slopes outward above, and is rough and slightly concave; it affords attachment to the soleus behind, the flexor longus digitorum above, and the flexor longus hallucis below.

The **proximal surface** of the head (Fig. 555) is little more than a border. It curves from in front backward and inward. Its anterior half bears an oblong facet which faces inward, upward, and backward, is covered with cartilage, and articulates with the facet on the lower side of the external tuberosity of the tibia. The facet is subject to considerable variation in size and extent: it sometimes occupies the

entire proximal surface, but more often is separated by a notch from the posterior angle, which is produced for ligamentous attachment.

The **Shaft** of the fibula is very slender, and difficult to describe. It is flattened from side to side, and at first sight appears to consist of two surfaces, an external and an internal, separated by two borders, an anterior and a posterior. A closer examination, however, reveals on strongly developed bones four borders, three well marked and one obscurely defined, which limit four surfaces.

The borders may be named the anterior-internal, the anterior-external, the posterior-external, the posterior-internal, and the surfaces the anterior, the external, the posterior, and the internal.

The **anterior-internal border** (Figs. 552, 555) is easily recognized as a sharp edge facing inward and forward. It is opposite the external border of the tibia, to which it is joined by the strong interosseous membrane; hence it is also known as the **interosseous ridge**. It begins above as the continuation of the anterior-inferior border of the head, runs vertically for a short distance, and then turns inward, becomes sharper and more prominent, and ends by bifurcating above the inferior extremity. The anterior branch of this division is continued straight down as the anterior border of the inferior extremity, and the posterior branch turns backward to form the posterior boundary of its anterior-external surface. The anterior-internal border separates the anterior from the posterior and internal surfaces.

The **anterior-external border** begins in common with the anterior-internal border and runs straight down to the lower third, where it gradually turns backward, approaches the posterior-external border, and fades out at a point proximal to the inferior extremity. It is never sharp nor prominent, and in some bones appears rather as the line of anterior maximum convexity than as a distinct border. It separates the anterior and external surfaces.

The **posterior-external border** (Fig. 554) is well marked. It begins above from the outer side of the lower end of the eminence on the back of the posterior-external surface of the head, and passes straight downward; it curves somewhat inward at the middle of the leg, and ends as the inner boundary of the posterior-external surface of the inferior extremity. This border is rounded above, but becomes sharp in the lower third. It separates the external and posterior

surfaces, and gives attachment to fascia separating the peroneal and flexor muscles.

The **posterior-internal border** is short and inconspicuous. It arises near the posterior-external border, but from the inner side of the posterior eminence of the head; it runs obliquely downward and forward and joins the anterior-internal border in the upper fifth of the bone. From its course it is also known as the **oblique line** of the fibula. It separates the small superior triangular internal surface from the larger posterior surface.

The **anterior surface** lies between the anterior-internal and anterior-external borders. It is very narrow above, but gradually becomes wider, and at the middle of the bone reaches its full width, which it retains almost to the end, where it again becomes pointed. It is rounded above, but for most of its length is flattened, and below slightly concave transversely. In its upper part it faces outward and forward; at the lower end it twists so as to face almost directly outward. For most of its extent it affords attachment to the peroneus brevis.

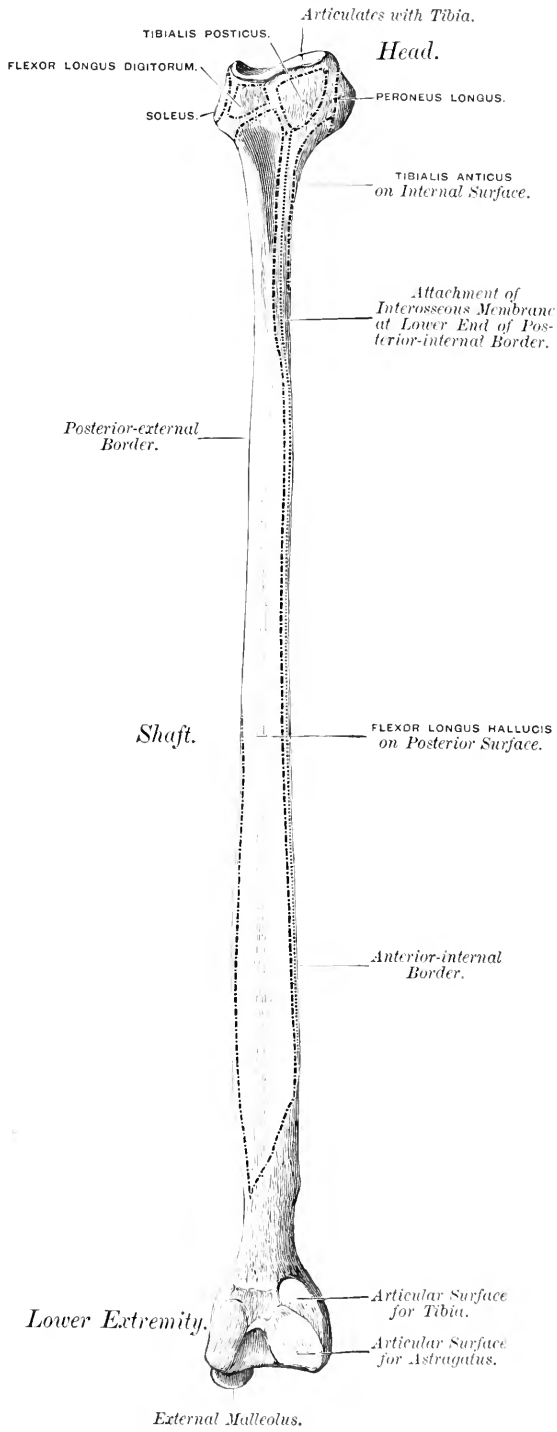
The **external surface** (Fig. 554) lies between the anterior-external and posterior-external borders. It is a narrow strip of equal width throughout its extent, convex transversely and gently sinuous vertically. It faces outward and backward, and affords attachment to the soleus and peroneus tertius.

The **internal surface**, included between the anterior-internal and posterior-internal borders, is limited to a very small triangle at the upper inner side of the bone. It faces inward and forward, is faintly concave, and is roughened to give origin to the tibialis anticus muscle.

The **posterior surface** (Fig. 555) is the largest and best defined, and lies between the posterior-internal and anterior-internal borders on one side and the posterior-external border on the other side. It is narrow in its upper fifth, below which it comprises the entire width of the bone. It is gently rounded transversely above, but for the most part is flat or faintly concave. It bends slightly toward the tibia at the middle, and faces backward and inward above and directly inward below. At about the lower limit of the upper fourth, near the anterior internal border, at the end of a long groove, is the **nutrient foramen**, which is directed downward. The surface gives attachment through its entire length to the flexor longus hallucis muscle.



FIG. 555.



LEFT FIBULA, INNER ASPECT.

The **Lower Extremity** is called the external malleolus. Its shape is that of a pyramid; the truncated apex is above and applied to the end of the shaft, and the base is below. The pyramid is flattened transversely, presenting a large inner surface and smaller anterior-external and posterior-external surfaces.

The **inner surface** (Fig. 555) is almost triangular. The lower margin or base of the triangle is transverse and faintly emarginate, the anterior and posterior margins are straight and slope from the distinct rounded angles upward toward the median line of the shaft. The inner surface is marked near the lower edge and behind the middle line by a deep, irregularly oval pit, in which and to the adjacent posterior angle is attached the strong ligament to the astragalus. Above this pit the surface is rough for the attachment of tibio-fibular ligaments. The anterior lower part of the surface is occupied by a large triangular articular facet, the edges whereof are sharply defined. The base of the triangle is vertical, one side formed by the lower margin and the other arching downward and forward to the anterior angle of the malleolus. The surface of the facet is transversely gently convex, and vertically concave above and convex below. It faces almost directly inward, is covered with cartilage, and is applied to the facet on the side of the astragalus. Above this facet is another smaller articular surface, which on the dried bone is not always clearly marked, but is very evident on a fresh bone. Its shape is also triangular; the base is on the anterior margin, and the apex points backward. Its plane slopes outward, upward, and forward from the other facet, and its surface therefore faces upward, forward, and inward. It is faintly concave from above downward, and fits on the convex facet on the posterior outer part of the lower extremity of the tibia.

The **anterior-external surface** (Fig. 554) is long and narrow, but wider below than above. It is bounded in front by the anterior margin of the malleolus, behind by the continuation downward of the anterior border of the shaft, and below by the distal margin. It is gently convex from above downward, and faintly convex from side to side; it is rough for the attachment of ligaments, and faces outward and forward. The lower end of its posterior border widens, and is produced downward and backward into a prominent flat **hook**, which is the lowest point of the fibula and is known as the **external malleolus proper**. Its oval, flat external surface and its edges furnish attach-

ment for ligaments, and its internal surface overhangs and forms the outer wall of a deep groove on the lower part of the posterior-external surface and the posterior part of the distal surface of the lower extremity of the bone. This groove is converted by bridge-like ligaments into a canal which transmits the tendons of the peroneus brevis and peroneus tertius muscles. Above this hook the posterior border of the anterior-external surface is interrupted by a broad, deep groove passing from the posterior-external surface downward and forward. This groove forms a canal for the tendon of the peroneus longus muscle.

The posterior-external surface is longer than it is wide, and has almost parallel sides, whereof the outer is common to it and the anterior-external surface, and the posterior is the continuation of the posterior-external border of the shaft directly downward and backward. The surface is gently concave from above downward, and faces backward and outward. Its lower part is grooved vertically in front for the tendons of the peroneus brevis and peroneus tertius muscles.

The lower surface is wider posteriorly to accommodate this groove, and for the rest of its extent transverse, sharp, and straight.

**Nomenclature.**—The first word for the fibula was *perone*, a pin, used by the Greeks for the fibula of the ox and other domestic animals, which ends below in a long point resembling a pin. Hippocrates used the term for the human bone. The Romans called pins and clasps *fibulæ*, and Vesalius introduced fibula into anatomy as the translation of *perone*. *Os perone* is sometimes used even now as a synonym, and we find the Greek word still employed in the term the *peroneal* muscles. The French word is *le péroné*; the German, *das Wadenbein*, from *wade*, the calf of the leg.

**Determination.**—When the fibula is held with the head upward and the broad, flattened posterior surface toward the student, the hook on the lower extremity is on the side to which the bone belongs.

**Articulation.**—The fibula articulates with the tibia and the astragalus.

**Muscular Attachments.**—The following muscles are attached to the fibula: to the head, the peroneus longus, the tibialis anticus, the tibialis posticus, the flexor longus digitorum, and the soleus; to the shaft, the tibialis anticus, the tibialis posticus, the flexor longus hallucis, the soleus, the peroneus tertius, and the peroneus brevis.

**Blood-Supply.**—The nutrient artery of the fibula is a branch of the tibialis posticus artery.

**Ossification.**—The fibula is developed from three centres, one for each extremity and one for the shaft.

#### VARIATIONS IN THE FIBULA.

##### VARIATIONS IN SIZE.

The measurements of the fibula are taken as follows:

The maximum length from the top of the head to the tip of the malleolus; the greatest transverse diameter of the head; the greatest transverse diameter at the lowest part.

Side.	Maximum length.	Diameter at upper end.	Diameter at lower end.	Side.	Maximum length.	Diameter at upper end.	Diameter at lower end.
Left . . . . .	87	7	7	Left . . . . .	99	9	8
Left . . . . .	88	7	7	Left . . . . .	99.5	8	8
Right . . . . .	89	7	7	Left . . . . .	100	8	8
Right . . . . .	90.5	9	9.5	Left . . . . .	100	8	8.5
Left . . . . .	91	8	7.5	Left . . . . .	100	8.5	8.5
Left . . . . .	91	8	8	Left . . . . .	100	9	8
Left . . . . .	91	8	7.5	Right . . . . .	100	9.5	8
Left . . . . .	91	9	7.5	Right . . . . .	100.5	8.5	8.5
Left . . . . .	91.5	8	8.5	Left . . . . .	101	9	7.5
Right . . . . .	91.5	8	7.5	Right . . . . .	101.5	9	9
Right . . . . .	91.5	8.5	8	Right . . . . .	102	7	7.5
Left . . . . .	92	8	7.5	Left . . . . .	102	9	9
Left . . . . .	93	7.5	8	Right . . . . .	102	9	8
Left . . . . .	93	8	8	Left . . . . .	103	8	8
Right . . . . .	93.5	8	8	Left . . . . .	104	8.5	8
Left . . . . .	94	8	8	Right . . . . .	105	8	8
Left . . . . .	94	9.5	8	Left . . . . .	105	10	9
Right . . . . .	94.5	9	10	Right . . . . .	105.5	10	9
Left . . . . .	95	8	8	Right . . . . .	106	7.5	8.5
Left . . . . .	95	8	7	Left . . . . .	108	8.5	9.5
Left . . . . .	96	7	8	Left . . . . .	108	9	8
Left . . . . .	96	7.5	8	Right . . . . .	109	8.5	9
Left . . . . .	96	8	8	Right . . . . .	109	9	8
Left . . . . .	97	6.5	8	Left . . . . .	109.5	9	9
Right . . . . .	97	7	8	Right . . . . .	110	10	10
Right . . . . .	97	7.5	8	Left . . . . .	110	10	9.5
Right . . . . .	97	8	8	Right . . . . .	110.5	10	9.5
Left . . . . .	97	8.5	8	Left . . . . .	111	10	9.5
Left . . . . .	97.5	8	8	Right . . . . .	111.5	9.5	9.5
Right . . . . .	97.5	8.5	9	Left . . . . .	112	9	9
Left . . . . .	97.5	8.5	8	Left . . . . .	113	8.5	9
Left . . . . .	98	8	8	Right . . . . .	114	8	8.5
Right . . . . .	98	9	9	Right . . . . .	114	8.5	8.5
Left . . . . .	98.5	7.5	8	Left . . . . .	119.5	9	9.5
Right . . . . .	98.5	9	8.5				

VARIATIONS IN FORM AND DEVELOPMENT.

The **posterior-external** surface of the head may become almost oval by the rounding of its angles, or may lose the regular pentagonal outline by the prolongation of one of the upper anterior angles. The upper margin may be straight or even produced at the middle (one case in eighty); when incised, the posterior part is the smaller, but may be produced upward into a small styloid process; the anterior part is rarely also produced upward; its proximal surface carries the facet for the tibia. The posterior-external surface passes through all grades of concavity from almost flat to extreme excavation. Of the two eminences the anterior as a rule is the larger, but the posterior may be greatly extended and continued down the anterior-external border of the shaft.

The **anterior-internal** surface of the head appears to vary in the degree of upward prolongation of the anterior part and in the degree of prominence of the posterior eminence which marks the beginning of the posterior-internal border of the shaft.

The **shaft** is apparently subject to slight variation. It is occasionally sinuate in the antero-posterior plane. Rarely the **anterior-external** border is prominent and almost as well marked as the anterior-internal and the posterior-external. The short **posterior-internal** border is at times very strong and appears as the upward continuation of the posterior-external border, or it may be absent, the twist of the bone alone indicating its position.

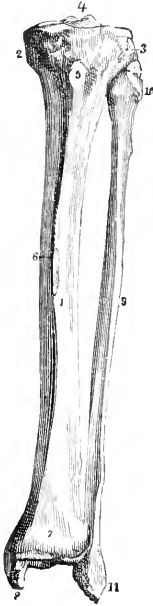
The outer aspect of the **lower extremity** exhibits variations in the degree of prominence of the oblique line forming the posterior border of the anterior-external surface. On many bones it is hardly indicated, and then the groove for the peroneus is very faint; on other bones it may be so prominent that its beginning at the end of the anterior-internal border of the shaft presents a tubercular enlargement. The malleolar process is always present; in one specimen examined, it was reduced to a mere tubercle. The variations on the inner aspect are variations in the size and distinctness of the articular facets and in the depth of the pit for the ligament near the lower margin.

**HUMAN FIBULA.**

The fibula in man is relatively shorter and stronger than in the cat (Figs. 556, 557).

The head is more spherical than in the cat, but when seen from the side has a similar outline. The external surface is prominent for the attachment of the biceps muscle and the long external lateral ligament; it lacks the deep vertical groove. The superior surface is almost circular; the articular facet for the tibia is at the posterior part. The styloid process is much more strongly developed, and to it is attached the short external lateral ligament. To the anterior part of the head is fastened the peroneus longus, and to the posterior part, the outer head of the soleus muscle.

FIG. 556.

LEFT FIBULA AND TIBIA,  
ANTERIOR VIEW.

1, shaft of the tibia; 2, 3, tuberosities; 4, spine; 5, tubercle; 6, crest of shin; 7, lower extremity of the bone; 8, internal malleolus; 9, shaft of the fibula; 10, its head; 11, external malleolus.

The borders on the shaft are all more clearly marked than they are in the cat, hence the bone is irregularly quadrilateral on cross-section.

The anterior-external border begins at the inner anterior side of the head, in common with the anterior-internal border. In its upper part it is obscure, but lower down it becomes very sharp and prominent. In the lower fourth it bifurcates, one branch going straight down as the anterior border of the lower extremity, the other passing downward and backward on the outer surface of the malleus. The triangle between the two branches is subcutaneous.

The anterior-internal border or interosseous ridge is not distinct from the anterior-external border in the upper fourth; lower down, however, it gradually diverges. In the lower fourth it is joined by the posterior-internal border, and then terminates at the apex of a rough triangle above the malleolar articular surface. It gives attachment to the strong interosseous membrane.

The posterior-internal border begins above at the posterior inner side of the head, and after taking a somewhat sinuous course terminates below in the anterior-internal border. It is particularly prominent at the middle of the bone, where it is pierced by the nutrient artery. It is sometimes called the oblique line of the fibula.

The posterior-external border begins above at the outer side of the head and passes to the posterior side of the shaft, and terminates as the posterior border of the malleolus.

The **external surface** is narrow above and wide below. In its upper third it is slightly convex transversely, but below this area it is concave down to the lower third, which is flat. The surface faces outward above, and outward and backward below; to it are attached the peroneus longus and peroneus brevis muscles.

The **anterior surface** is much narrower than the external, especially above, where it does not begin until the anterior-external and anterior-internal borders begin to diverge. It is grooved longitudinally, and affords attachment to the extensor longus digitorum, peroneus tertius, and extensor proprius hallucis muscles.

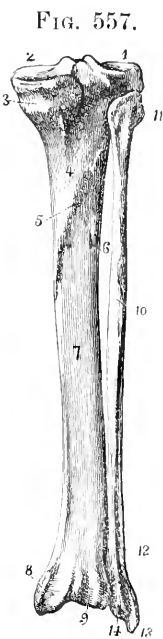
The **internal surface** is between the anterior-internal and posterior-internal borders; it is narrow above and below, and grooved to give origin to the tibialis posticus muscle.

The **posterior surface** is between the posterior-internal and posterior-external borders. It is a wide surface, wider, however, below. It is so twisted that, while it faces backward above, it faces backward and inward in the middle and directly inward below. To its roughened upper part is attached the soleus muscle; from the rest of the surface down to a roughened oblique line for a ligament at the lower end arises the flexor longus hallucis muscle.

The **lower extremity** is more simple than in the cat; its general shape is pyramidal. Its **external** (anterior-external) surface is separated from the **posterior** (posterior-external) surface by the oblique branch of the anterior-external border of the shaft. It is not obliquely grooved for tendons, nor has it the terminal posterior-inferior hook.

The **internal surface** presents a triangular facet for the astragalus, below and behind which is a deep depression for the external lateral ligament.

The **posterior surface**, sometimes called the posterior border, is broad, and slightly concave for the passage of the tendons of the peroneus longus and peroneus brevis muscles.



RIGHT FIBULA AND TIBIA,  
POSTERIOR VIEW.

1, 2, articular surfaces of the tibia for the condyles of the femur, separated by the tibial spine; 3, the inner tuberosity; 4, surface occupied by the popliteal muscle, defined by the popliteal line, 5; 6, nutrient foramen; 7, surface covered by the flexors of the toes; 8, internal malleolus; 9, grooves for tendons; 10, interosseous ridge; 11, head of the fibula; 12, subcutaneous surface at the lower part of the bone; 13, external malleolus; 14, groove.

## THE TARSUS.

**General Description.**—The proximal division of the foot is constituted, like the carpus, of seven small bones closely united; it differs, however, from the carpus in important details. In the first place, it is much longer, forming a third of the entire foot and being a third as long as the tibia, whereas the carpus forms but an eighth or ninth of the hand and is only a twelfth as long as the ulna. In the second place, its articulation with the lower ends of the leg bones is not by means of a well-defined proximal surface, but, because of the backward development of the heel bone, is effected by a large articular swelling on the dorsal surface, a condition which greatly limits the amount of backward and forward motion, or flexion, of the foot upon the leg.

The proximal end of the tarsus is formed by the narrow end of the heel bone, from which the lateral margins diverge to the middle of the tarsus, whence they are parallel for the rest of their extent. The outline of the tarsus as seen from the dorsal aspect may therefore be said to be formed of a proximal triangle, whereof the base is applied to a distal square.

The tarsus has four surfaces, the dorsal, the plantar, the proximal, and the distal, and two borders, the tibial and the fibular.

The dorsal surface is narrow, and little more than a border in the proximal two-sevenths; in the next two-sevenths it is wider, and swollen into a prominent, spool-like articular eminence; and for the remaining three-sevenths it is quadrate, smooth, and convex from side to side, with the maximum convexity on the tibial side of the middle line. The dorsal surface forms part of the instep.

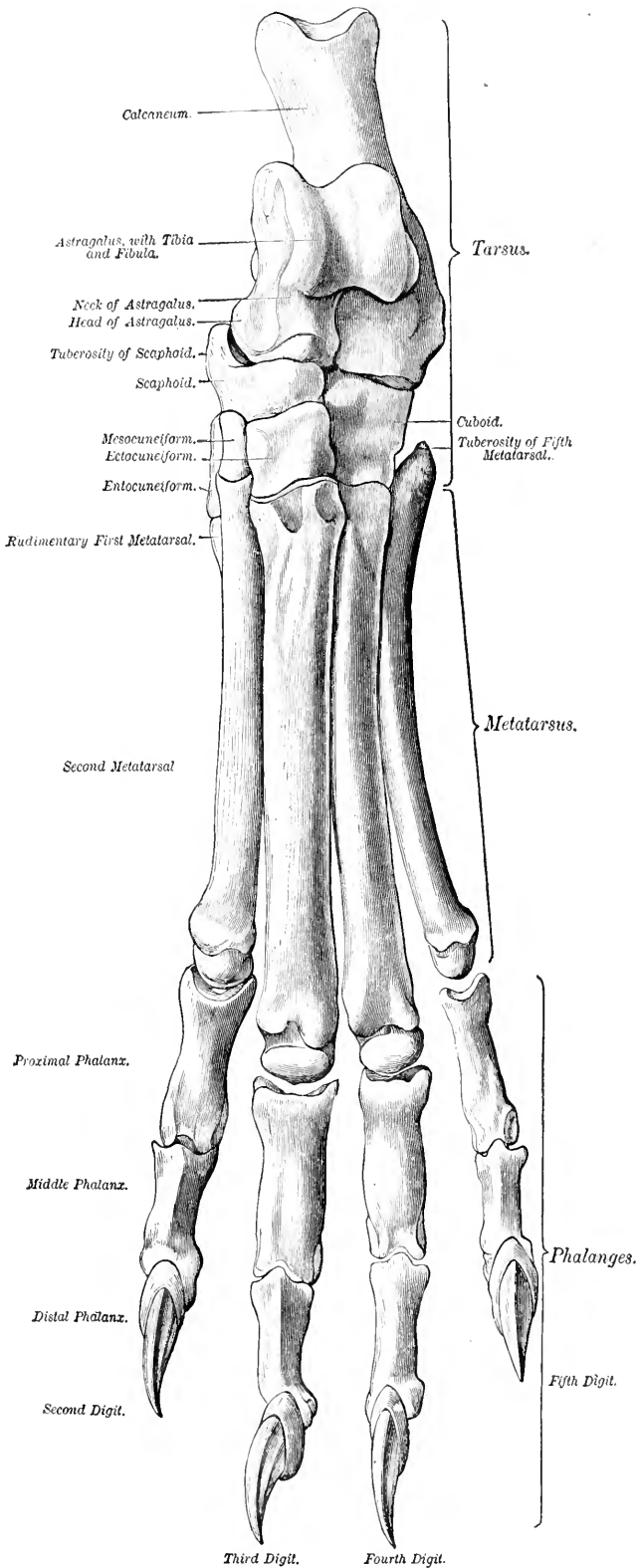
The plantar surface has the general outline of the dorsal surface, but is flatter. The proximal half is transversely convex and smooth; the distal half is irregularly depressed and elevated for ligamentous attachment. The plantar surface forms part of the sole of the foot.

The proximal surface is the circular end of the heel bone.

The distal surface is transversely oval, or, more accurately, slightly crescentic, with the arcuate border on the dorsal side and the straight, or slightly emarginate, border on the plantar side. It is not perfectly flat, but elevated and depressed, owing to the different lengths of the constituent tarsal bones. It is highest in the middle and at the tibial end, and most depressed between the middle and the tibial end.



FIG. 558.



LEFT FOOT, DORSAL ASPECT.

The tibial and fibular borders of the tarsus, formed by the meeting of the dorsal and plantar surfaces, are well defined in the distal half only, inasmuch as the proximal heel bone is compressed strongly from side to side.

The seven bones of the tarsus differ in arrangement from the corresponding carpal bones. Two bones are arranged in the proximal row, four are placed in a transverse distal row, and the seventh bone occupies a position between the two rows and on the tibial side. The two bones which form the proximal row are not side by side, as are the scapho-lunar and cuneiform of the hand, but one is placed dorsal to the other. The other bones do not radiate from the proximal end of the tarsus toward the lateral margins, but are arranged parallel to the long axis of the foot, and in such manner that four lie on the tibial side and one on the fibular side of a longitudinal suture. The dorsal of the two proximal bones is the ankle bone, or the **astragalus**, and the ventral is the heel bone, or the **calcaneum**. The **scaphoid** is the middle bone, which is situated between the two rows. In the distal row, counting from the tibial side, are the **entocuneiform**, the **mesocuneiform**, the **ectocuneiform**, and the **cuboid**.

The tarsal bones are six-sided, and present (*a*) dorsal and plantar surfaces, which are non-articular, but assist in forming the instep and the sole of the foot respectively; (*b*) proximal and distal surfaces, which, except on the astragalus and the calcaneum, articulate respectively with the distal and proximal surfaces of adjoining tarsal and metatarsal bones; and (*c*) tibial and fibular surfaces, either articulating respectively with the fibular and tibial surfaces of adjoining tarsal bones, or producing the fibular and tibial borders of the tarsus.

**Nomenclature.**—Tarsus is from *tarsos*, used by the Greeks for a number of objects with broad flat surfaces, such as the blade of a rudder, a saw, or basket-work for drying fruit. Later, it was applied to the broad part of the hand and of the foot, exclusive of the fingers or the toes, and without any reference to the bones contained therein. It was first used in osteology by Galen, who included in it, however, only the four bones of the distal row, counting the three others as independent elements. The anatomists of the Middle Ages restricted the name to the back part of the foot, which has since borne it. The Germans call the tarsus *die Fusswurzel*, the French *le tarse*.

Three sets of names are employed for the tarsal bones: (1) the

Anglicized Latin names used by English and American anatomists; (2) the Latin names used by European Continental anatomists; and (3) the more general names adopted by comparative anatomists.

1	2	3
Astragalus.	Talus.	Tibiale.
Calcaneum.	Calcaneum.	{ Intermedium. { Fibulare.
Navicular or Scaphoid.	Scaphoideum.	Centrale.
Internal cuneiform.	Entocuneiforme.	Tarsale I.
Middle cuneiform.	Mesocuneiforme.	Tarsale II.
External cuneiform.	Ectocuneiforme.	Tarsale III.
Cuboid.	Cuboideus.	Tarsale IV. + V.

### THE ASTRAGALUS.

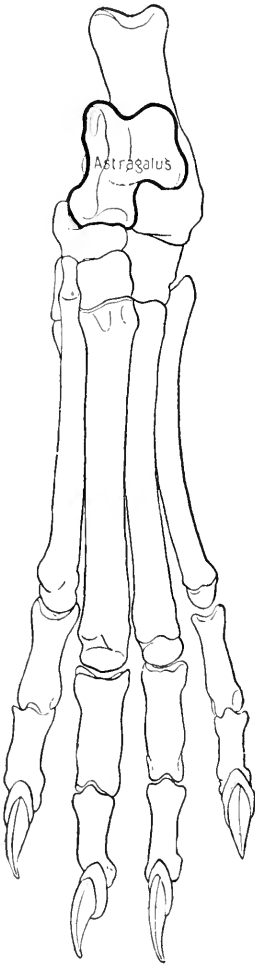
**General Description.**—The Astragalus is the dorsal bone in the proximal row of the tarsus (Fig. 559). It is not so large as the calcaneum, but is much larger than any one of the other tarsal bones. It is easily known by its stout, square body, which bears on its dorsal surface the large, pulley-like articular surface for the tibia, and also by its head, which is separated from the body by a neck and projects prominently from the rest of the bone. The astragalus alone of all the tarsals enters into the formation of the ankle-joint, and to it is transmitted through the tibia the weight of the body. While it covers the middle part of the calcaneum, it leaves uncovered the distal part and the fibular side of the proximal part. It possesses six surfaces, the dorsal, the fibular, the plantar, the tibial, the distal, and the proximal.

The dorsal surface (Fig. 560) is divided into three parts,—that of the bone proper, that of the neck, and that of the head. The first of these parts is nearly square, and is occupied by the trochlea.

The trochlea is shaped like a segment of a pulley; it is convex from before backward, and exhibits high, sharp sides and a deep central groove. The surfaces sloping from the edges to the bottom of the groove are convex from side to side; the surface on the fibular side is wider, flatter, and higher than that on the tibial side and has a more clearly defined external margin. The groove, therefore, lies near the tibial margin of the surface. The trochlea does not lie in the same

vertical longitudinal plane as the whole bone, but is directed from the proximal end distally and to the fibular side. The centre of the distal

FIG. 559.



POSITION OF ASTRAGALUS.

end of the trochlea is situated at the beginning of the fibular margin of the neck; the tibial part of the trochlea is continued on the neck as its dorsal surface. This surface of the neck is convex from side to side and concave from its distal to its proximal end, and is perforated by a number of small foramina; it gives origin to fibres of the extensor brevis digitorum muscle. It is continued distally as the dorsal surface of the head.

The fibular or external surface of the body (Fig. 566) is crescentic, and is limited on the proximal and dorsal sides by the convex line of the trochlea, which arches from the proximal end, distally and to the plantar side, and forms an angle with the distal margin, which is truncate and directed proximally and to the plantar side. The plantar margin is prominent in its distal part, but becomes obscure proximal to the middle and is lost in the rough pit for the insertion of the strong ligament from the inner surface of the external malleolus. Almost the entire surface is occupied by a curved, pyriform, articular surface for the external malleolus. The broad part is distal; the narrow part is proximal. The space at the proximal end

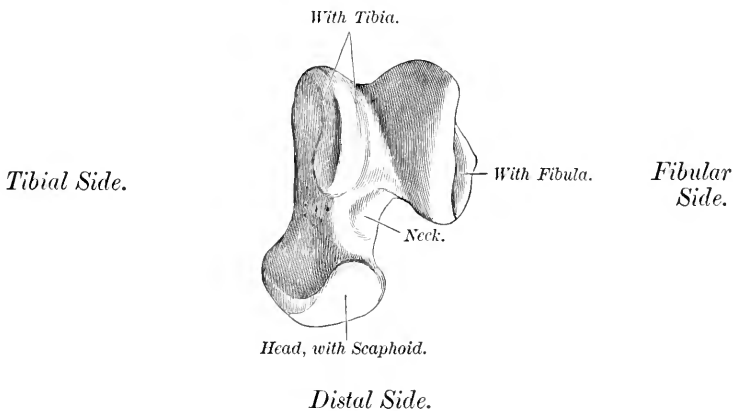
not occupied by this articular surface is the rough pit already mentioned. The surface is nearly flat, slightly concave at the distal end, and faces toward the fibular side and slightly proximally. A small, oblong fibular surface is shown on the side of the neck and head; it is concave and rough.

The proximal or posterior surface (Fig. 563) is the continuation of the trochlea toward the plantar side. It is triangular; the apex of the triangle is plantar; the sides are prolongations of the sides of the trochlea. It is directed obliquely to the plantar and tibial sides, and is deeply grooved for the passage of the flexor muscles of the foot. The

proximal surface faces at first dorsally and proximally, and then proximally and to the plantar side.

The tibial or internal surface (Fig. 561) differs from the external in lying in one plane, and therefore cannot be well divided into parts for the body, the neck, and the head. It is limited at the proximal end and at the proximal half of the dorsal margin by the arcuate edge of the trochlea; the distal half of the dorsal margin is emarginate as far as the end of the head. The distal margin is arcuate, and the plantar border is arcuate for the distal half and emarginate for the proximal half. Along the proximal and dorsal margins is a narrow

FIG. 560.  
*Proximal Side.*

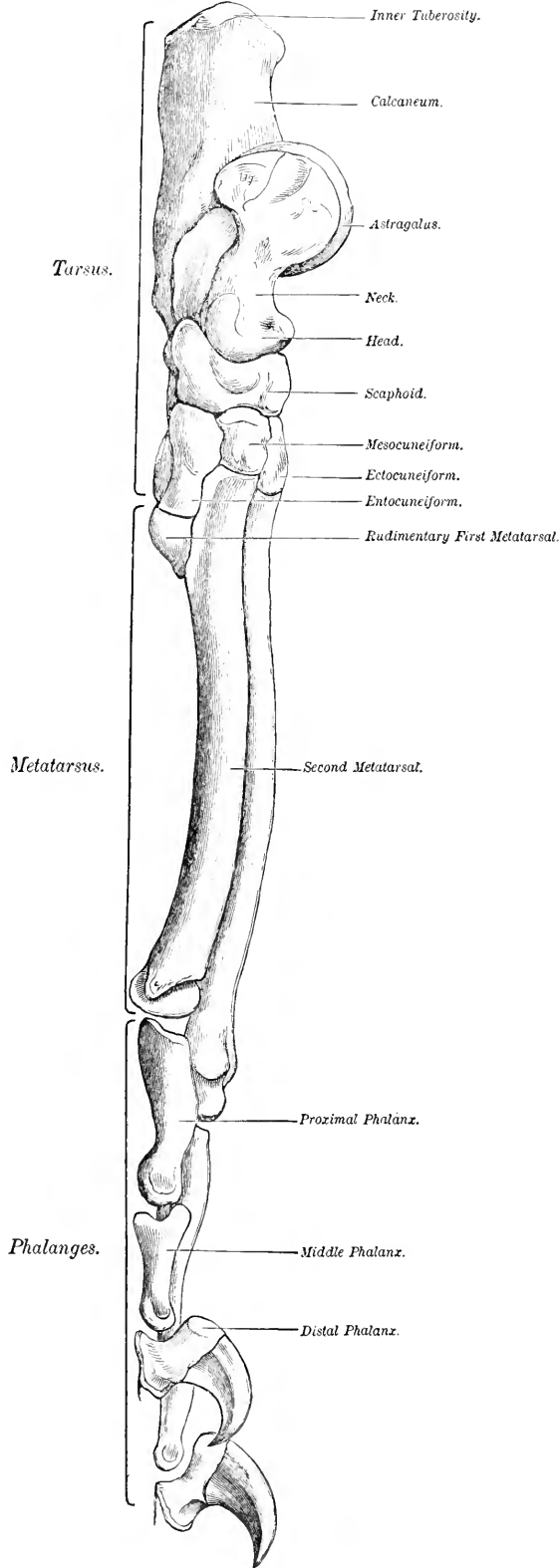


LEFT ASTRAGALUS, DORSAL SURFACE.

facet for the fibular side of the internal malleolus. This facet is narrow where it begins at the proximo-plantar angle and expands at the dorsal end. On the plantar side of the facet is a rough area for the insertion of a ligament. Distal to this area, where the neck begins, is a pit, marked by a number of small foramina. The surface of the neck is slightly rough; it is encroached upon at the distal and plantar side by that extension of the articular surface of the head which joins the tuberosity of the scaphoid.

The distal or anterior surface (Fig. 562) is limited to the front of the head; it is oval, the large diameter running obliquely from the tibial side dorsally and to the fibular side. The margins are all rounded, and are seen on the other aspects of the head. The surface is convex in both directions, and fits into a corresponding concave surface on the proximal surface of the scaphoid.

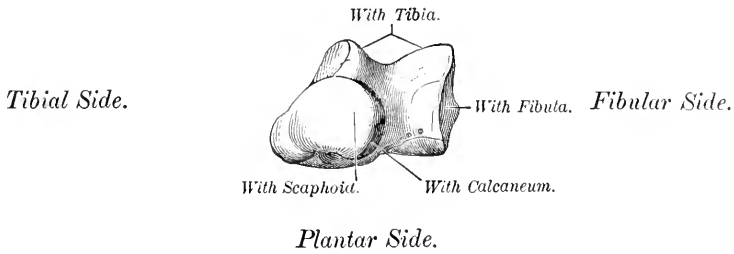
FIG. 561.



LEFT FOOT, INNER ASPECT.

The plantar or inferior surface (Fig. 563) is very irregular. Its general shape is that of a rectangle, whereof the tibio-distal angle is produced into the neck and head. Almost the entire surface is occu-

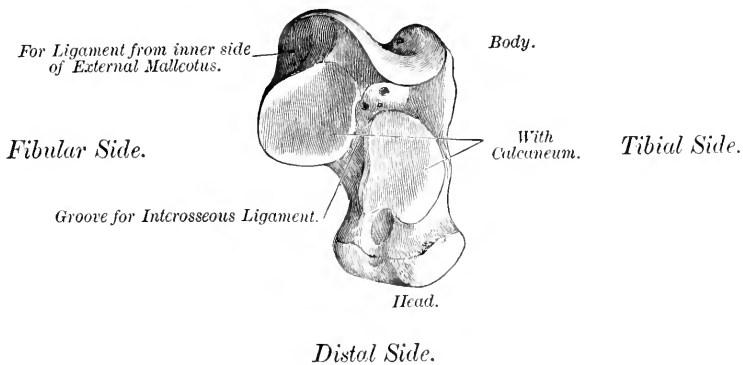
FIG. 562.  
*Dorsal Side.*



LEFT ASTRAGALUS, DISTAL ASPECT.

pied by two large, complicated, articular facets for the calcaneum. The larger of these facets lies along the fibular side of the body and resembles an oblong rectangle with the long diameter running somewhat obliquely from the proximal to the distal end. The distal margin is arcuate; the proximal margin is arcuate, and is also the fibular margin of the proximal surface. The fibular margin is emarginate, and is the plantar border of the fibular surface. The tibial margin is emarginate, and separated from the rest of the plantar surface and from the other

FIG. 563.  
*Proximal Side.*



LEFT ASTRAGALUS, PLANTAR SURFACE.

facet by a deep oblique groove. The facet is concave in the longitudinal line and slightly concave from side to side. It is so twisted on itself that, while the distal part faces to the plantar, proximal, and

tibial sides, the proximal part faces to the plantar, distal, and fibular sides. The second facet lies on the tibial side between the deep oblique groove and the tibial margin. It occupies the distal half of the body, and is continued on the neck. It leaves a small, deeply depressed surface of the body free at the tibio-proximal angle, continuous with the oblique groove and under the short proximal margin. The articular facet is oval, gently convex in both directions, and articulates with the facet on the dorsal surface of the lesser process of the calcaneum. A narrow articular line is carried from it along the fibular margin of the neck and joins a triangular facet at the proximo-fibular part of the plantar surface of the head for articulation with the corresponding line and anterior expansion on the tibial side of the distal part of the surface of the calcaneum. The rest of the under surface of the head and neck of the astragalus is convex. In the middle line is a deep oval pit for the attachment of a ligament which runs to the plantar border of the proximal surface of the scaphoid.

**Nomenclature.**—Astragalus is a Greek name for a die, and in the earliest times the knuckle bones from sheep and goats were used as dice. The Latin *talus*, with the same meaning, is also employed as a name for this bone, particularly by European writers. In comparative anatomy the astragalus is known as the *tibiale*. The Germans translate *astragalus* into *das Wurfelbein*, or use the better term *das Sprungbein*. The French synonym is *l'astragale*.

**Determination.**—If the bone be held with the dorsal or trochlear surface upward and the head toward the student, the head will be on the side to which the bone belongs.

**Articulation.**—The astragalus articulates with the tibia on the dorsal and tibial sides, with the fibula on the dorsal and fibular sides, with the calcaneum on the plantar side, and with the scaphoid distally.

**Muscular Attachment.**—To the dorsal surface of the astragalus is attached a part of the *extensor brevis digitorum*.

#### THE CALCANEUM.

**General Description.**—The Calcaneum is the largest bone of the tarsus (Fig. 564). Its entire length and width show only on the plantar surface of the foot; its dorsal surface is partly covered by the astragalus. It does not enter into the articulation of the ankle-joint.

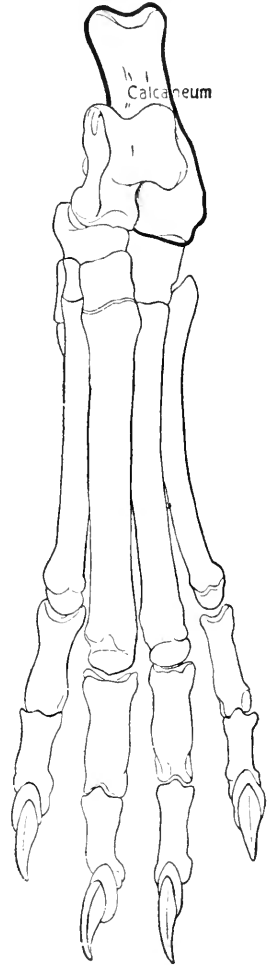


It is an oblong, irregular bone, with the greatest length double the greatest width from the tibial to the fibular side. It is wider at the distal than at the proximal end. The greatest width, however, is found just distal to the middle, where a prominence known as the **lesser process** projects laterally to the tibial side. The average width is scarcely one-third the length. The proximal narrower portion is compressed from side to side, and the distal wider portion is flattened from the dorsal to the plantar side. The distal part is sometimes called the **greater process** of the bone. The plantar aspect is smooth; the dorsal aspect is irregular, and marked by eminences and depressions. The calcaneum presents for examination six surfaces, the dorsal, the plantar, the internal or tibial, the external or fibular, the proximal, and the distal.

The **dorsal surface** (Fig. 565) consists of a proximal and a distal portion of nearly equal length. Inasmuch as the proximal or posterior part of both the external and the internal surface slopes from the plantar edge dorsally and to the middle line of the foot, the proximal part of the dorsal surface becomes little more than a border, which is rounded from side to side and concave from end to end. It is separated behind from the proximal surface by the crescentic proximal margin, which is sometimes sharp and everted. When the sole of the foot is wholly on the ground this surface faces outward as well as upward. The part of the dorsal surface distal to this portion becomes wider and more prominent; it is convex and slopes abruptly to the plantar side and passes into the distal part of the dorsal surface. On this sloping portion are two facets for articulation with the astragalus.

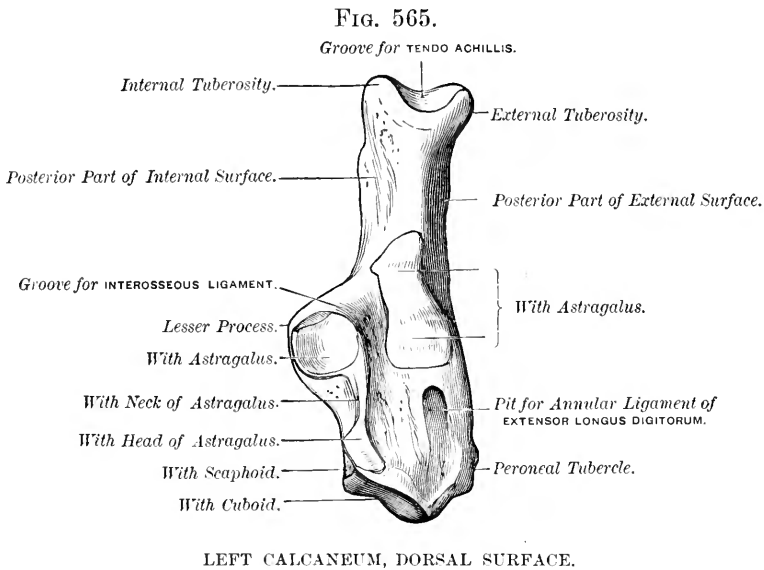
The **fibular facet** begins on the tibial or internal surface of the bone near its dorsal border, and is directed distally and to the fibular side. It is twice as long as wide, and strongly convex from end to end, except just at the distal end, which passes into the wide part

FIG. 564.



POSITION OF CALCANEUM.

of the dorsal surface of the bone, where it is concave. It is less convex from side to side, except at the distal end, which is concave. Its proximal margin is rounded; the tibial margin is emarginate and separated from the other facet by a rough groove for the interosseous ligament from the astragalus. The distal margin is slightly arcuate, and the fibular margin is emarginate above and arcuate below. The surface faces at first dorsally, to the tibial side and slightly proximally; then dorsally, to the tibial side, and distally; it articulates with a surface on the fibular side of the plantar surface of the astragalus.



The other facet lies mainly on the tibial side, on the dorsal surface of the lesser process, and is continued distally along the tibial border of the dorsal surface proper. The part on the lesser process is almost circular, and slightly concave; it faces dorsally and proximally; a small proximal area, however, is not on the same plane as the rest, but faces dorsally and to the proximal and tibial sides. The fibular side of the facet is continued forward on the tibial margin as a narrow line, which widens and ends at the tibio-distal angle in a uniform concavo-convex surface which faces to the dorsal and proximal sides. The facet and its prolongation forward articulate with a corresponding elongated facet on the tibial side of the plantar surface of the body, neck, and head of the astragalus.

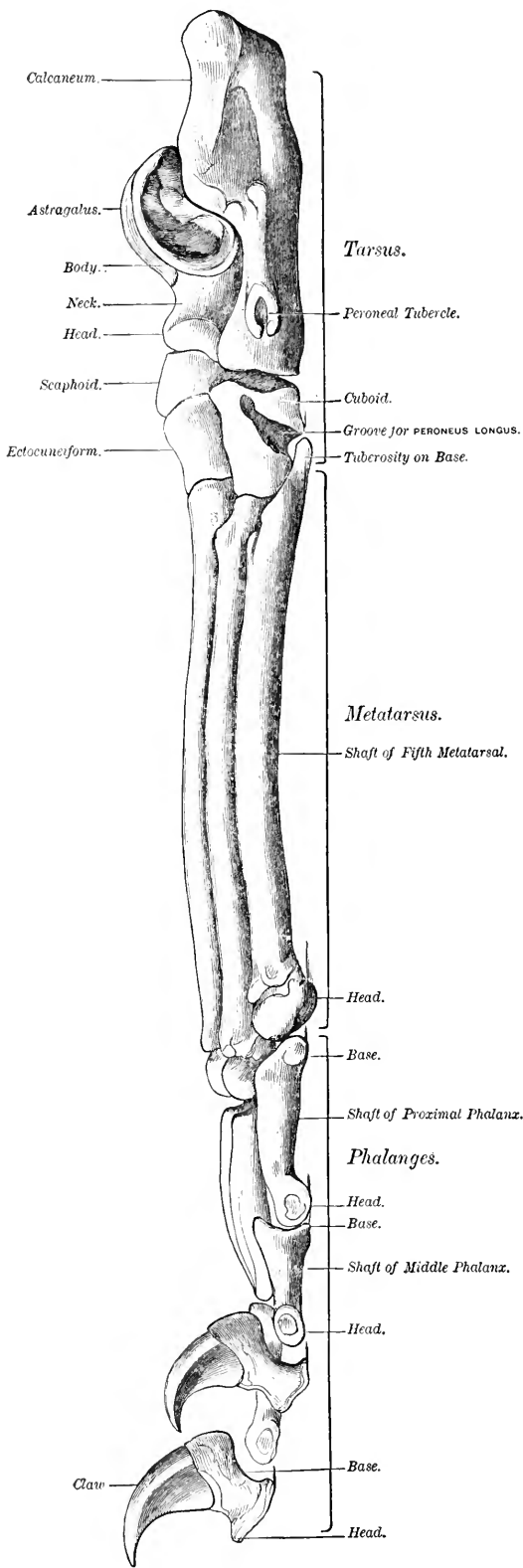
The remaining distal part of the dorsal surface of the calcaneum is four-sided. The proximal margin is continuous with the facets and

the groove which separates them. The fibular margin is well defined and runs straight forward from its proximal half, and is produced laterally near the distal end by the **peroneal tubercle**, beyond which it is emarginate and directed obliquely to the tibial side. The distal margin is prominent and arcuate, and passes obliquely to the tibial and proximal sides. The tibial margin is limited by the prolongation forward of the tibial articular facet already described. This part of the dorsal surface is rough and concave, and faces dorsally and to the tibial side. A decided groove runs near the fibular border and parallel with it and affords origin to the extensor brevis digitorum muscle, and by a pit at the proximal end receives the insertion of the annular ligament for the extensor longus digitorum.

The **fibular or external surface** (Fig. 566) is high from the dorsal to the plantar border in its proximal two-thirds, and low in its distal third. The proximal margin is rounded, passing below into the outer tuberosity and above into the sharp proximal margin of the dorsal surface. Its dorsal margin, beginning at the proximal end, is at first emarginate, then arcuate, then turns abruptly to the plantar, distal, and fibular sides, and is continued for the rest of its length as a straight and prominent border. At its distal end is a flat projection, whereof the plantar surface is crossed by a deep groove passing obliquely from the border distally and to the tibial side. The projection is called the **peroneal tubercle**, and the groove transmits the tendon of the peroneus longus muscle. There is no decided plantar margin, inasmuch as the fibular surface passes without a definite line into the plantar surface. The proximal part of the fibular surface is prominent and known as the **outer tuberosity**; distal to which, however, it is concave in both directions, and often marked by a distinct pit for the insertion of a part of the external lateral ligament. When the bone is in position, this part of the fibular surface faces nearly directly outward. The distal part of the surface is limited to the border; all that part beneath is regarded as part of the plantar surface.

The **tibial or internal surface** (Fig. 561) in its proximal two-thirds resembles in shape the corresponding part of the fibular surface. It is strongly concave from the proximal to the distal end to permit the passage of the flexor tendons from the back of the ankle to the sole of the foot. At its highest point at the distal end is seen part of the fibular articular facet for the astragalus. At the junction of the

FIG. 566.

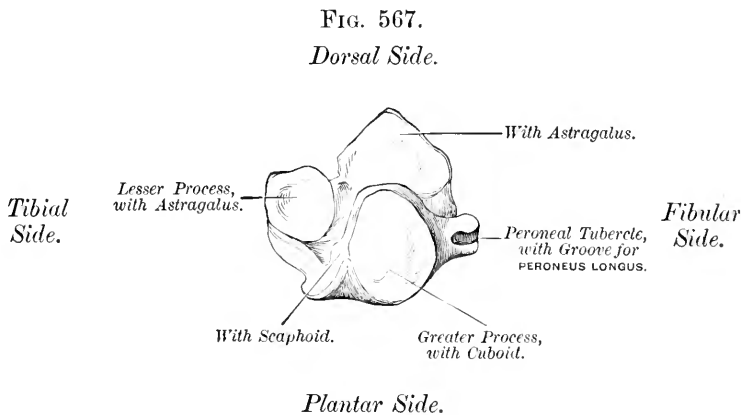


LEFT FOOT, OUTER ASPECT.

anterior and the middle third of the tibial aspect is the lesser process, or sustentaculum, a semicircular shelf-like projection directed distally and toward the dorsal side. Its dorsal surface is concave, and forms part of the dorsal surface of the bone; its tibial surface is convex, and gives attachment to the inferior calcaneo-scaphoid ligament; its plantar surface is deeply grooved to transmit the tendon of the flexor longus digitorum muscle.

Distal to the lesser process, the tibial surface is rough for the attachment of the inferior calcaneo-scaphoid ligament. At its dorsal margin is seen the expansion of the front of the tibial facet on the dorsal surface. At its distal margin is a small facet, which articulates with a facet on the fibular border of the scaphoid near its proximal end.

The distal surface (Fig. 567) is a smooth, round, or oblong articular surface for the cuboid; it is almost flat, or slightly concave, from above downward, and convex from side to side, and faces to the tibial



LEFT CALCANEUM, DISTAL ASPECT.

side as well as distally. Its margins are arcuate, but the tibial is not well defined, and bears a flattened triangular area which joins the fibular side of the proximal surface of the scaphoid.

The proximal surface is oval, with the long diameter vertical. Its lateral margins are prominent and swollen into more or less marked tuberosities. Of these, the inner, or tibial, is the larger. The plantar border is rounded. Almost the entire proximal surface is occupied by a wide, vertical groove, in which lies the tendon of the great extensor muscle of the foot. Just above the plantar margin is a curved line, which marks the dorsal limit of the insertion of this

tendon. The dorsal margin consists of an inner or tibial slightly concave part which passes obliquely outward and upward to meet the proximal part of the dorsal surface of the bone, and a shorter outer or fibular part which runs nearly vertically to meet the tibial part in a dorsal angle.

On the **plantar surface** (Fig. 587) the proximal margin is transverse and rounded, but well defined. The tibial margin begins at the inner tuberosity of the heel, runs distally as an indistinct border, and becomes apparent as a ridge dividing the groove on the plantar surface of the lesser process from the plantar surface proper. The fibular margin is less marked proximally, inasmuch as the fibular surface is concave and passes gently into the plantar surface; its distal part is well defined, running at first distally to the fibular side as far as the peroneal tubercle, and then distally and to the tibial side. The greater part of the plantar surface is convex from side to side; it is depressed at the distal end, on a line running obliquely from the tibial side, distally and to the fibular side, parallel with the distal end of the fibular border.

**Nomenclature.**—Calcaneum is derived from *calx*, the heel. *Os calcis* is used, and also *os calcaris*, from *calcara*, a spur, because the spurs are worn on the heel. The German equivalent is *das Fersenbein*, the French *le calcaneum*.

**Determination.**—When the calcaneum is held with the dorsal surface uppermost and the distal surface toward the student, the lesser process is on the side to which the bone belongs.

**Articulation.**—The calcaneum articulates with the astragalus, the cuboid, and the scaphoid.

**Muscular Attachments.**—The calcaneum affords origin on its dorsal surface to the **extensor brevis digitorum**; on the plantar surface to the **abductor minimi digiti** and the plantar head of the **flexor longus digitorum**.

**Ossification.**—The calcaneum appears to be developed from a single centre of ossification.

#### THE SCAPHOID.

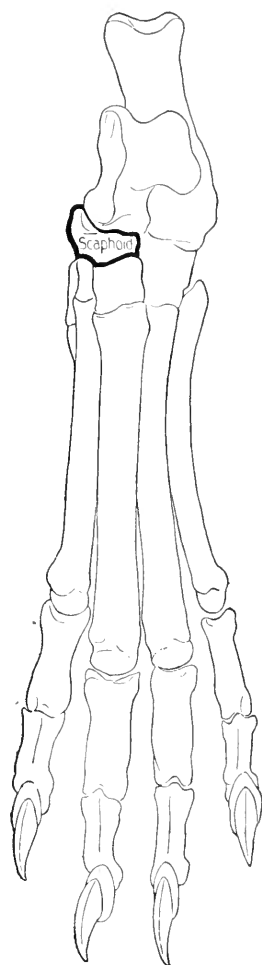
**General Description.**—The Scaphoid is the first bone on the inner or tibial side of the second row of the tarsus (Fig. 568). It lies distal to the astragalus, proximal to the three cuneiforms, and on the

tibial side of the cuboid. It may be recognized by its shape, which is wholly different from that of any of the carpal or other tarsal bones. It is flat and rectangular; its vertical or dorso-plantar diameter is one-fifth larger than the transverse or tibio-fibular; its greatest length, between the proximal and distal borders, is only one-half the length of the dorso-plantar diameter. The tibio-plantar angle of the proximal surface is produced into a prominent blunt process called the **tuberosity**. The scaphoid has the six surfaces common to tarsal bones.

The **proximal surface** may be recognized at once by its deep cup shape. Its general outline is oblong, the tibio-fibular diameter being about one-fourth less than the dorso-plantar. Its dorsal margin is arcuate, and passes into the tibial and fibular margins; the tibial border is slightly emarginate, and directed somewhat toward the tibial side for its dorsal half; it then becomes arcuate, and is continued in a tibial, plantar, and proximal direction as the tibial margin of the tuberosity. The outer or fibular border is emarginate and forms a rounded angle with the plantar border. Near the angle and partly on the fibular surface (Fig. 569) is a small convex facet, which faces proximally and to the fibular side, and articulates with a concavity on the tibial margin of the distal end or greater process of the calcaneum. The plantar border runs from this angle to the root of the tuberosity, where it may be said to end, since the plantar margin of the tuberosity, which is continuous on the inside with the tibial margin, runs dorsally, distally, and to the fibular side, and is lost in the lower plantar part of the proximal surface proper.

The proximal surface presents three more or less distinct parts. The largest is the oblong, concave, cup-shaped facet for the distal end of the head of the astragalus. It occupies nearly all the surface except the plantar third. The region around the tibio-plantar angle is the dorso-fibular surface of the tuberosity, and lies in a different

FIG. 568.

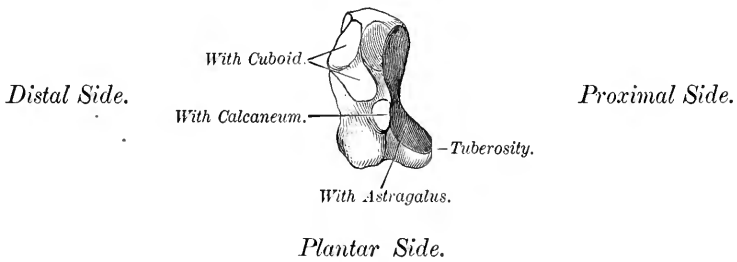


POSITION OF SCAPHOID.

plane; it is slightly concave, and articulates with the tibial side of the head of the astragalus. The region about the fibulo-plantar angle is separated from the large facet by an oblique line, the continuation of the plantar border of the tuberosity, dorsally and to the fibular side; the region is rough for the attachment of the astragalo-scaphoid ligament.

The **dorsal surface** is not so long as it is wide. It has its proximal and distal borders sharp and parallel, diverging slightly on the tibial side. Its fibular margin, although rounded, is well defined; on the tibial side the surface passes regularly into the tibial surface. It is convex from side to side, slightly concave in the proximo-distal direction. It is smooth, and in some specimens gives origin to a part of the extensor brevis digitorum muscle.

FIG. 569.  
*Dorsal Side.*



LEFT SCAPHOID, FIBULAR SURFACE.

The **tibial surface** (Fig. 561) presents no articular facets; it is oblong, slightly rough, and convex in both directions. The plantar proximal part is produced into the tuberosity. Its proximal margin is sharp and emarginate, with its plantar third bent nearly at right angles to the dorsal part, limiting the proximal surface of the tuberosity. Its plantar margin is parallel with this part of the proximal margin, forming also the tibial margin of the plantar surface of the tuberosity. Its distal margin is well defined, and almost straight in a dorso-plantar direction; it is somewhat irregular, because it limits the irregular facets on the distal surface.

The **plantar surface** (Fig. 587) is L-shaped, one branch of the L running in a proximal direction and representing the plantar surface of the tuberosity, the other branch passing transversely as the surface of the bone itself. Its margins are all rounded, and it is convex for the attachment of the plantar ligaments.

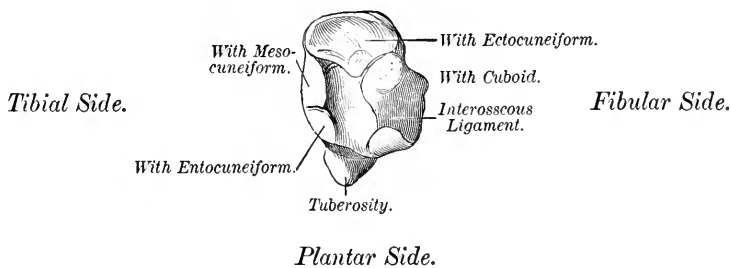


The **fibular surface** (Fig. 569) is oblong; its dorsal margin is horizontal and rounded. The upper part of the proximal margin is emarginate; the lower part is arcuate and rough, and passes into the rough area at the fibulo-plantar angle of the proximal surface. The plantar margin is swollen; the distal margin is indistinct, except where it is also the margin of the large facet on the distal surface. The whole surface is irregular, and for the most part gives attachment to the ligament which binds the bone to the cuboid.

On the dorsal half of the surface is an elongated, sometimes crescentic, **facet** which extends from near the dorso-distal angle downward and backward nearly to the proximal margin. It is deeply concave from the dorsal to the plantar side, and articulates with the tibial side of the cuboid. On the proximal margin itself is another smaller facet which meets a corresponding facet on the side of the greater process of the calcaneum, as already described. The facets on the fibular surface vary in relative position and in size; they are distinctly marked only in the recent state.

The **distal surface** (Fig. 570) has the outline of a square. Three corners are rounded off; the fourth, the tibio-plantar, is produced in

FIG. 570.  
*Dorsal Side.*



LEFT SCAPHOID, DISTAL SURFACE.

the tuberosity. About half of the surface is rough for the attachment of the interosseous ligament, and about half is occupied by articular facets for the cuneiform bones.

The largest of these facets lies at the dorsal and fibular sides. It is somewhat triangular, the base of the triangle being its dorsal margin, which is also the dorsal border of the distal surface, and the apex near the centre of the bone and separated from the larger of the two remaining facets by a deep pit for a ligament and from the facet for

the cuboid on the fibular surface by a rough triangle. It is slightly concave from side to side, and convex from above downward, and articulates with the proximal surface of the ectocuneiform.

The second facet lies along the tibial margin below the facet for the ectocuneiform. It is vertically oval, and slightly convex, and articulates with the proximal end of the mesocuneiform.

The third facet lies also on the tibial border, just below the preceding, from which it is separated by an elevated line. It is small, nearly round, and convex in both directions; it faces toward the plantar aspect as well as distally, and articulates with the proximal surface of the entocuneiform.

**Nomenclature.**—The scaphoid is often known as the navicular. Both terms are inflections of the Greek and Latin words meaning a boat, whence our words skiff and navy. The Germans call it *das Kahnbein*, and the French *le scaphoïde*.

**Determination.**—The scaphoid is easily recognized by its shape and by the presence of the tuberosity. If the smooth dorsal surface be held upward, and the irregular distal surface toward the student, the tuberosity will be on the side to which the bone belongs.

**Articulation.**—The scaphoid articulates on the proximal side with the astragalus and slightly with the calcaneum, on the distal side with the cuneiforms, and on the fibular side with the cuboid.

**Ossification.**—The scaphoid is developed from a single centre of ossification.

#### THE ENTOCUNEIFORM.

**General Description.**—With the exception of the mesocuneiform, the Entocuneiform is the smallest bone of the tarsus. It lies distal to the scaphoid, proximal to the rudimentary first metatarsal, and on the tibial and plantar sides of the mesocuneiform and the base of the second metatarsal (Fig. 571). It is an elongated, flat bone, twice as long as it is wide. When the tarsus is seen squarely from the front or dorsal side, only a narrow strip of the entocuneiform is visible as the tibial edge. It presents five surfaces, the dorso-tibial, the plantar, the fibular, the proximal, and the distal.

The dorso-tibial surface (Fig. 561) is the only one which is visible on the back and inner side of the tarsus. The proximal part of its dorsal margin is oblique, meeting the distal straight part in an obtuse angle; the proximal and distal margins are straight and nearly parallel,

and at right angles to the dorsal margin; the plantar margin is not distinct from the plantar surface. The dorso-tibial surface is convex from the dorsal to the plantar aspect of the foot, and slightly concave from the heel to the toe, and affords insertion for the tibialis posticus muscle.

The **plantar surface** (Fig. 587) is limited on the tibial side by the dorso-tibial surface, and on the fibular side by a distinct margin which separates it from the fibular surface. It is wider at the proximal end than at the distal, and is really but a continuation of the dorso-tibial surface on the sole of the foot. It is rough for the attachment of ligaments, whereof one passes to the ectocuneiform and prevents the mesocuneiform from appearing on the plantar aspect of the foot.

The **distal surface** is sharply defined. It is kidney-shaped, narrower above than below; the longer side is on the dorso-tibial border, and the long axis runs obliquely from the dorsal to the plantar side. It is slightly concave, and articulates with the base of the rudimentary first metatarsal.

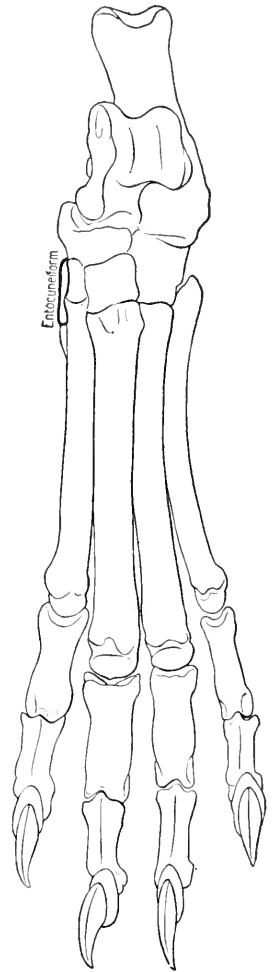
The **proximal surface** (Fig. 583) is small and oval, and its greater diameter is vertical. It is slightly cup-shaped, and faces as much to the fibular and dorsal sides of the foot as to the heel. It articulates with an oval facet on the tibial margin of the distal surface of the scaphoid.

The **fibular surface** (Fig. 572) presents a distal and a proximal half.

The distal half has nearly straight and parallel dorsal and plantar borders, which are at right angles to a straight distal border. It is rough and depressed, and connected by strong ligaments to the tibial side of the second metatarsal.

The proximal half appears to be bent away from the long axis, and is directed to the sole of the foot. Its dorsal part is depressed; the plantar part is prominent, and bears a small facet more or less

FIG. 571.



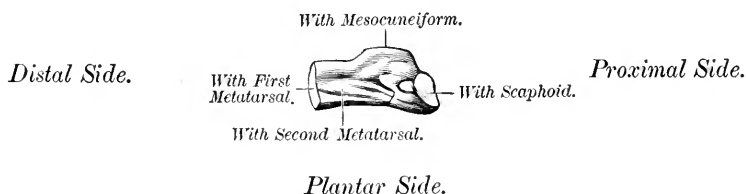
POSITION OF ENTOCUNEIFORM.

well defined for the mesocuneiform. The surface slopes in a plantar, tibial, and proximal direction in nearly the same plane as the proximal surface.

**Nomenclature.**—Entocuneiform is the Latin *cuneiform*, wedge-shaped, with the Greek prefix *ento*, inner. Internal cuneiform is often used as a synonym, which is the same as the German *das innere Keilbein*. *Os cuneiforme primum* is preferred by European anatomists. The French use *le premier cunéiforme*. Comparative anatomists designate the entocuneiform as *tarsale I*.

FIG. 572.

Dorsal Side.



LEFT ENTOCUNEIFORM, FIBULAR SURFACE.

**Determination.**—If the dorso-tibial surface be held upward and the flat truncate distal surface toward the student, the straight side will be on the side to which the bone belongs.

**Articulation.**—The entocuneiform articulates on the proximal side with the scaphoid, on the fibular side with the mesocuneiform and second metatarsal, and by its distal end with the rudimentary first metatarsal.

**Muscular Attachments.**—The tibialis posticus is attached to the entocuneiform.

**Ossification.**—The entocuneiform is developed from one centre.

### THE MESOCUNEIFORM.

**General Description.**—The Mesocuneiform is the smallest bone in the tarsus. It lies distal to the scaphoid, proximal to the second metatarsal, and wedged in between the other two cuneiforms in such a way that it does not reach the plantar surface of the foot (Fig. 573). It is nearly square, and somewhat prismatic; it presents five surfaces, the dorsal, the tibial, the fibular, the proximal, and the distal.

The proximal surface (Fig. 574) may be distinguished from the distal surface by its small size and its more regularly oval shape. Its

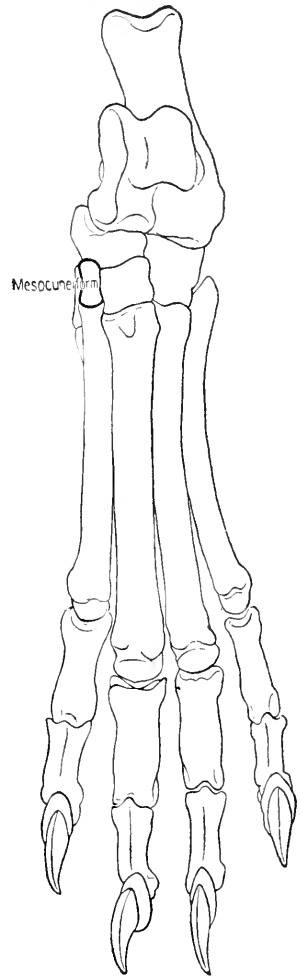
long axis is almost vertical; it is slightly concave, and faces toward the fibular side of the foot as well as toward the heel. It articulates with the oval facet on the tibial margin of the distal surface of the scaphoid.

The distal surface (Fig. 575) is more or less pear-shaped; the large end is on the dorsal side, the narrow end points to the sole of the foot. There is usually a decided emargination on the fibular border above the middle for the attachment of a strong interosseous ligament. The distal surface articulates with the proximal surface of the base of the second metatarsal.

The dorsal surface (Fig. 558) is nearly square, or slightly longer than wide. Its distal and fibular borders are straight and meet at a right angle; the proximal border is straight, but runs somewhat obliquely from the fibular end to the tibial side and toward the heel. The tibial border is therefore slightly longer than the fibular, and passes from the distal end to the tibial side as well as proximally. The dorsal surface is convex from side to side, and rough for the attachment of ligaments. It faces in a dorso-tibial direction. Its tibio-proximal angle slopes to the sole of the foot.

The tibial surface (Fig. 576) also is in general rectangular, and the disto-plantar angle is slightly produced. The surface is for the most part rough and depressed for the attachment of the strong ligament from the ectocuneiform. Its proximal

FIG. 573.



POSITION OF MESOCUNEIFORM.

FIG. 574.

*Plantar Side.*

*Tibial Side.*

*With Scaphoid.*



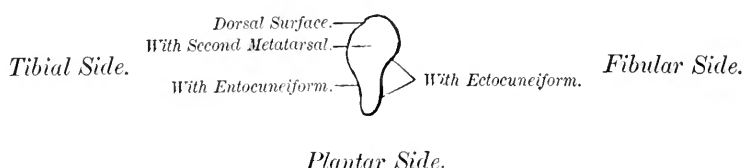
*Fibular Side.*

*Dorsal Side.*

LEFT MESOCUNEIFORM, PROXIMAL SURFACE.

border is slightly elevated, and shows an obscure facet for articulation with the proximal part of the fibular surface of the ectocuneiform. The tibial surface faces toward the sole of the foot as well as toward the tibial side. There is no plantar surface, merely a rounded plantar border.

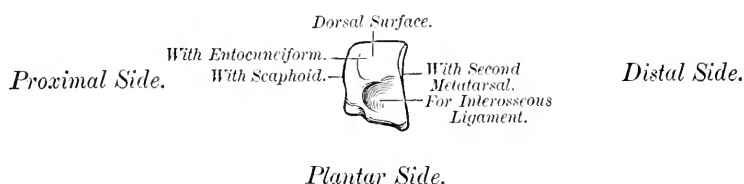
FIG. 575.  
*Dorsal Side.*



LEFT MESOCUNEIFORM, DISTAL SURFACE.

The fibular surface has the general shape of the tibial surface, that is, square, with one angle, the disto-plantar, prolonged. The proximal border shows two facets which articulate with a small and slightly convex semilunar facet, or two facets, on the proximal border of the tibial surface of the ectocuneiform. The surface is rough below for an interosseous ligament.

FIG. 576.  
*Dorsal Side.*



LEFT MESOCUNEIFORM, TIBIAL SURFACE.

**Nomenclature.**—Mesocuneiform is compounded of *meson*, middle, and *cuneiform*, wedge-shaped. Middle cuneiform, *os cuneiforme secundum*, and *tarsale II.* are also used. In German we find *das zweite oder mittlere Keilbein*, and in French *le deuxième cunéiforme*.

**Determination.**—When the bone is held with the dorsal surface uppermost and the proximal surface toward the student, the flat, fibular side faces to the side to which the bone belongs.

**Articulation.**—The mesocuneiform articulates with the scaphoid, the ectocuneiform, the entocuneiform, and the second metatarsal bone.

**Ossification.**—The mesocuneiform is developed from one centre.

### THE ECTOCUNEIFORM.

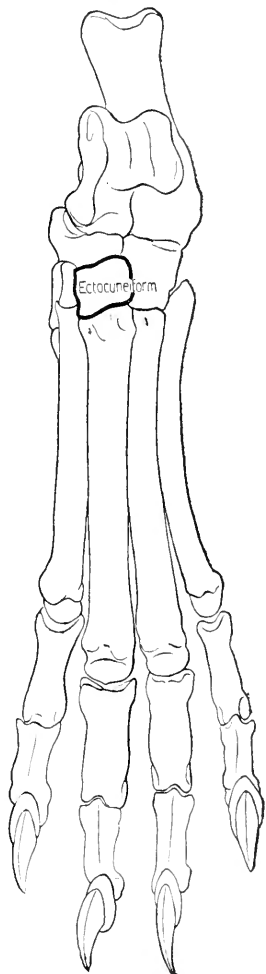
**General Description.**—The Ectocuneiform is placed about in the centre of the distal row of tarsal bones (Fig. 577). It may be said to be in the main axis of the foot, inasmuch as distal to it lies the principal digit, to which the direct weight of the body is transmitted through the ectocuneiform, the scaphoid, the astragalus, and the tibia. This cuneiform is easily distinguished from the other cuneiforms by its superior size and complexity, and from the cuboid by the absence of the block-like form and deep groove of the latter.

The ectocuneiform is prismatic, one side of the prism forming the dorsal surface and the other two sides forming the lateral surfaces; at the proximal and distal ends it is cut off squarely; the plantar aspect is produced into a prominent vertical hook, whereof the concave side faces toward the digits and holds in place the tendon of the peroneus longus on its way to insertion on the first rudimentary metatarsal. The ectocuneiform presents five surfaces, the dorsal, the tibial, the proximal, the distal, and the fibular. Of these the dorsal is non-articular, and the other four articulate with contiguous bones. The end of the plantar hook is the only true plantar surface.

The proximal surface (Fig. 578) is triangular, with the base of the triangle formed by the dorsal border and the sides by the tibial and fibular borders, which meet below at the rounded apex. The base is about as long as a line drawn from the base to the apex. The dorsal margin is gently and regularly arched; the lateral borders are slightly arcuate above the middle, while below they are nearly straight and directed obliquely to the middle line. The dorso-tibial angle is more prominent than the dorso-fibular.

The proximal surface is entirely occupied by one facet, which is large, triangular, and smooth for articulation with a facet on the dorsal

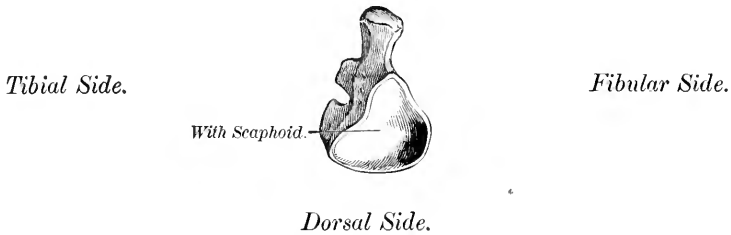
FIG. 577.



POSITION OF ECTOCUNEIFORM.

and fibular side of the distal surface of the scaphoid. It is concave from above downward, and also slightly concave from side to side. It does not lie throughout in one plane, but is twisted in such a manner that, while the dorsal part faces toward the heel and slightly to the tibial side, the plantar part faces toward the heel and the fibular side.

FIG. 578.

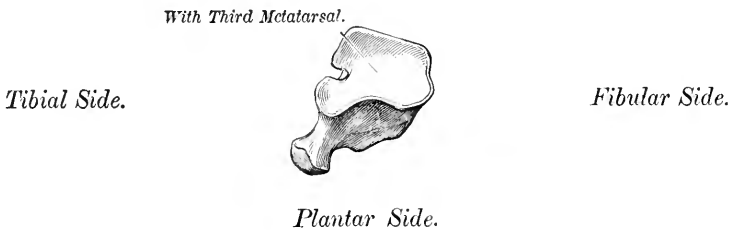
*Plantar Side.*

LEFT ECTOCUNEIFORM, PROXIMAL SURFACE.

The dorsal surface (Fig. 558) is almost square; the proximo-fibular angle is a little sharper than the others. All four margins are well marked; the distal is straight, the others may be faintly emarginate. The surface is convex from side to side, and rough for the attachment of part of the extensor brevis digitorum muscle.

The distal surface (Fig. 579) is in general triangular, often T-

FIG. 579.

*Dorsal Side.*

LEFT ECTOCUNEIFORM, DISTAL SURFACE.

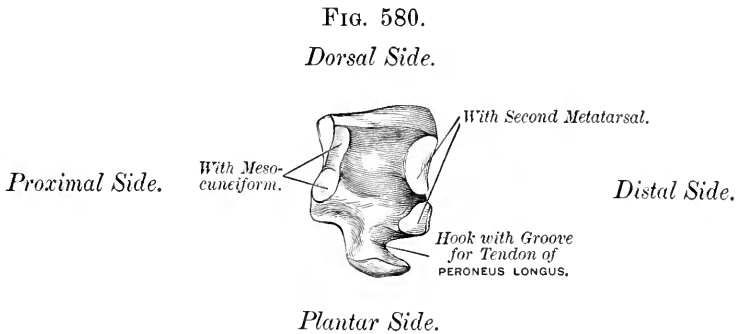
shaped. It consists of a dorsal oval part, about twice as wide as high, and a narrow, nearly vertical strip, which runs to the tibial side as well as toward the sole of the foot; its plantar extremity is more or less expanded transversely. The dorsal border is arched from side to side, and turns around into the two side margins, whereof the fibular is the longer and runs down obliquely to the tibial side. Its dorsal



part is arcuate, the middle part emarginate, and the plantar end either straight or slightly emarginate, and meets the tibial border at a more or less defined plantar angle. The tibial border runs more vertically than the fibular, and is arcuate or angular above and deeply emarginate below the middle. The lower part is arcuate, passing downward and to the fibular side to form the plantar angle.

The entire surface is smooth, and faintly concave from above downward; it articulates with a corresponding triangular proximal surface of the base of the third metatarsal.

The **plantar surface** (Fig. 587) consists of the plantar surface of the hook-like process. This is oval and twice as long as wide; the long diameter passes obliquely from the proximal to the tibial side. It is convex, and gives attachment to ligaments.



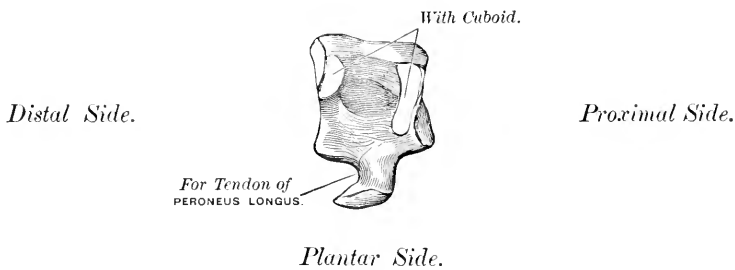
LEFT ECTOCUNEIFORM, TIBIAL SURFACE.

The **tibial** and **fibular surfaces** are very similar, and can be distinguished only by close attention to several small details. They are nearly square; the proximal border is shorter than the distal, and the dorsal border is shorter than the plantar. The dorsal border is somewhat rough; the proximal and distal borders are sharply defined, and the plantar border is not well marked, because for most of its length it gives support to the base of the plantar hook-like process of the bone. It can be located by drawing a line between the proximal and distal plantar angles. The **hook** consists of a base and a head. The base is applied to the plantar border, which, owing to the prismatic form of the bone, is a border common to the tibial and fibular surfaces and represents all there is of a true plantar surface. The base of the hook is compressed from side to side and narrows from before backward to form a neck, whereon is placed the head, which is wider than the

base, and extends distally, forming the hook proper. Both surfaces are concave, especially near the middle, and rough for ligamentous attachment. The principal difference between the two surfaces lies in the formation of the region near the distal border.

On the **tibial surface** (Fig. 581) there are two prominent distal swellings, one dorsal and one plantar, separated by a deep groove which produces the decided emargination on the tibial side of the distal surface. These swellings are smooth, and articulate with corresponding depressions on the fibular side of the base of the second metatarsal bone.

FIG. 581.  
*Dorsal Side.*



LEFT ECTOCUNEIFORM, FIBULAR SURFACE.

On the **fibular surface** only the upper of these swellings is present, and it is not so prominent; it articulates with a facet on the dorso-distal angle of the tibial surface of the cuboid. There runs along the proximal margin on each surface an elongated vertical facet; it is more distinctly marked on the fibular than on the tibial surface. On the fibular side it articulates with a long facet in the middle of the tibial surface of the cuboid; on the tibial side it articulates with the fibular side of the mesocuneiform. As stated above, each lateral surface is continued downward into the narrower lateral surface of the plantar hook.

**Nomenclature.**—Ectocuneiform is from the Greek *ecto*, without, and the Latin *cuneiform*, wedge-shaped. External cuneiform, *os cuneiforme tertium*, and *tarsale III.* are also used. The German equivalent is *das dritte* or *äussere Keilbein*, the French *le troisième cunéiforme*.

**Determination.**—The ectocuneiform is known by its hook. When the dorsal surface is held uppermost and the T-shaped distal surface toward the student, the smaller deeper excavation on the fibular side of the latter surface is on the side to which the bone belongs.

**Articulation.**—The ectocuneiform articulates with the scaphoid on the proximal side, with the mesocuneiform and the second metatarsal on the tibial side, with the third metatarsal on the distal side, and with the cuboid on the fibular side.

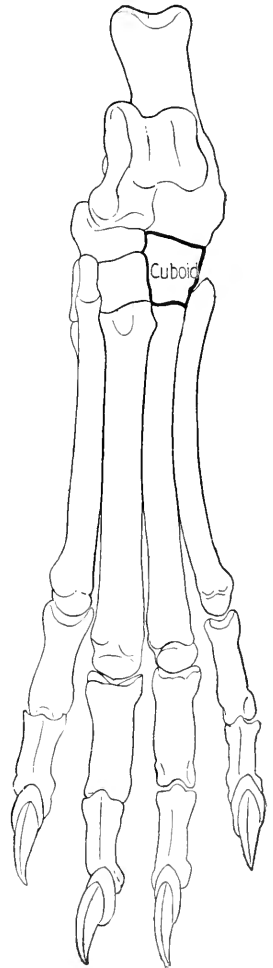
**Ossification.**—The ectocuneiform is developed from one centre of ossification.

### THE CUBOID.

**General Description.**—The Cuboid is the bone on the outer, or fibular, side of the distal row of the tarsus (Fig. 582). It lies distal to the calcaneum and proximal to the fourth and fifth metatarsals. The scaphoid and ectocuneiform are on its inner or tibial side. It is a regular bone without processes, but deeply grooved for the passage of a tendon. It has six surfaces, whereof three are occupied by articular facets for the contiguous bones mentioned, and the other three are rougher for the attachment of ligaments and muscles. The articular surfaces are the proximal, the distal, and the tibial; the non-articular are the dorsal, the fibular, and the plantar.

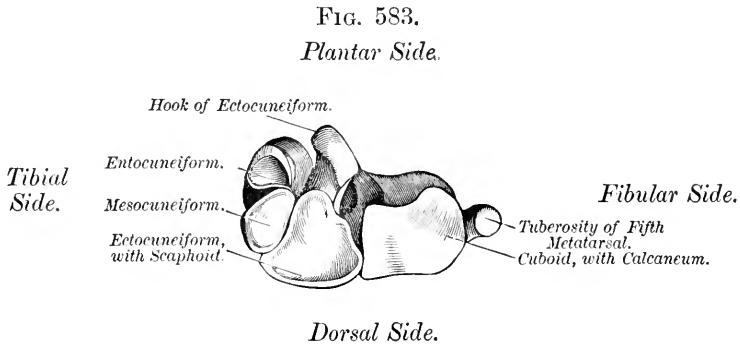
The proximal surface (Fig. 583) is roughly quadrilateral, somewhat wider from side to side than high from the instep to the sole. Its dorsal and tibial margins are nearly straight, and meet at right angles. The tibio-plantar angle is somewhat truncate, and the plantar border is emarginate for most of its extent, but arcuate at the fibulo-plantar angle, which is produced downward. The fibular border is in general slightly arcuate, but emarginate near the dorso-fibular angle where the groove begins. The proximal surface is smooth, and covered with cartilage for articulation with the distal surface of the calcaneum. It is not flat, but so twisted that the tibial side faces toward the heel and the dorsum of the foot, and the fibular part, with the produced lower outer angle, faces directly toward the heel.

FIG. 582.



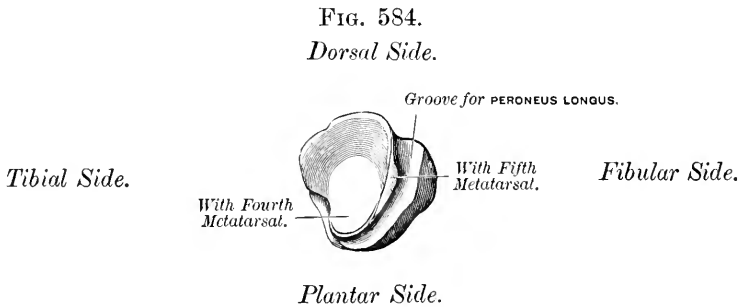
POSITION OF CUBOID.

The distal surface (Fig. 584) is ear-shaped and concave, and articulates with the base of the fourth metatarsal. The arcuate borders are on the dorsal, fibular, and plantar sides, and the emarginate border is on the tibial side. The emargination on the tibial border is due to a



THE DISTAL ROW OF TARSAL BONES IN POSITION, PROXIMAL ASPECT.

decided pit in the distal part of the tibial surface, in which is inserted an interosseous ligament. All the borders of the surface are sharp, except a portion of the fibular, which is flattened and turned to the fibular side to articulate with the elevated base of the fifth metatarsal.

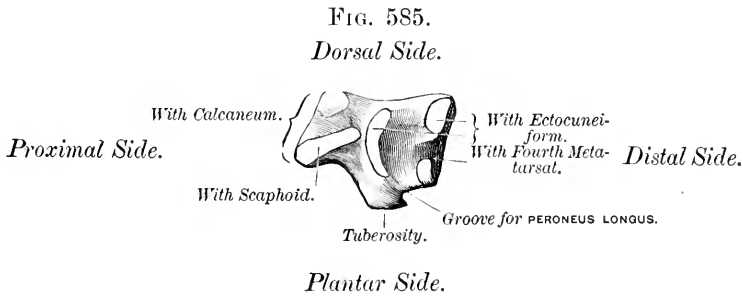


LEFT CUBOID, DISTAL SURFACE.

The tibial surface (Fig. 585) is the third which is articular. Its outline is irregular; the dorsal border is nearly straight or slightly emarginate; the distal border is also emarginate, but more strongly, and meets the dorsal and plantar borders at right angles. The proximal border is oblique, running from the proximo-plantar angle dorsally and distally. The greater part of the plantar border is deeply emarginate; in front of the middle is a projection, which is the end of the elevated portion of the plantar surface, sometimes known as the tuberosity of the cuboid. The distal border of this projection is emarginate,

and with the rest of the plantar border of the tibial surface marks the end of the peroneal groove.

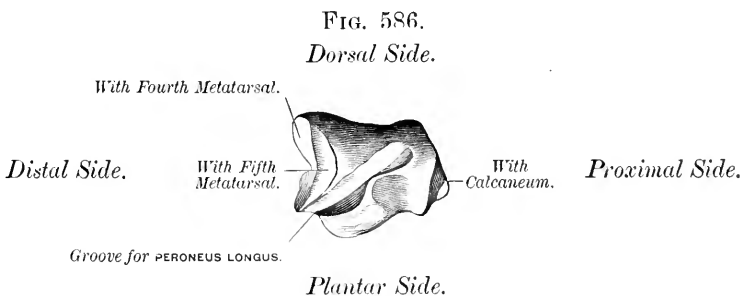
The surface is irregular, marked by small elevations and depressions for the attachment of ligaments. An elongated, articular facet begins near the proximo-plantar angle and runs obliquely dorsally and distally. Above this facet, near the dorso-proximal angle, in some specimens there is a second oval facet. These facets articulate with corresponding facets on the fibular side of the scaphoid. Near the



LEFT CUBOID, TIBIAL SURFACE.

middle of the surface is a narrow, slightly curved articular facet which runs obliquely from the root of the so-called tuberosity dorsally and proximally. This facet and another smaller one near the dorso-distal angle are for articulation with the ectocuneiform. These facets are subject to variation, usually in the line of a reduction of the articulating surfaces.

The dorsal surface (Fig. 558) is almost rectangular, twice as long as it is wide, convex from side to side, and gently concave from the



LEFT CUBOID, FIBULAR SURFACE.

proximal to the distal end. It is wider near the proximal border than at the opposite end. The lateral borders are somewhat emarginate; the ends are nearly straight.

The **fibular surface** is also rectangular, and is divided into two parts by an oblique groove which begins near the dorsal and proximal borders and runs to the disto-plantar angle. The portion in front of the groove is smaller than the portion behind, which is much more prominent and is continued on the **plantar surface** as a broad ridge, namely, the **tuberosity** of the cuboid. This ridge runs from near the proximo-fibular angle to the distal part of the tibial margin. In front of the ridge is the continuation of the groove already mentioned for the tendon of the peroneus longus. On the ridge is the common origin of the adductor indicis, the adductor minimi digiti, and the opponens minimi digiti. Behind the ridge the plantar surface is concave, depressed, and rough for ligamentous insertion. The distal border of the fibular surface is flattened, and articulates with the base of the fifth metatarsal.

**Nomenclature.**—Cuboid is compounded of *cubus*, a cube, and *eides*, like. *Os cuboideum* is very generally used, also, less frequently, *cuboides*. The cuboid is formed by the union of the *tarsalia IV.* and *V.* of comparative anatomists. The Germans use *das Würfelbein*, the French *le cuboïde*.

**Determination.**—The cuboid is known by its oblong, rectangular form and by the deep groove on the fibular and plantar surfaces. When the smooth dorsal surface is held uppermost, and the distal surface is toward the student, the rough tibial surface points to the side to which the bone belongs.

**Articulation.**—The cuboid articulates proximally with the calcaneum; on the tibial side with the scaphoid and the ectocuneiform; on the fibular side slightly with the fifth metatarsal bone; and distally with the fourth and fifth metatarsal bones.

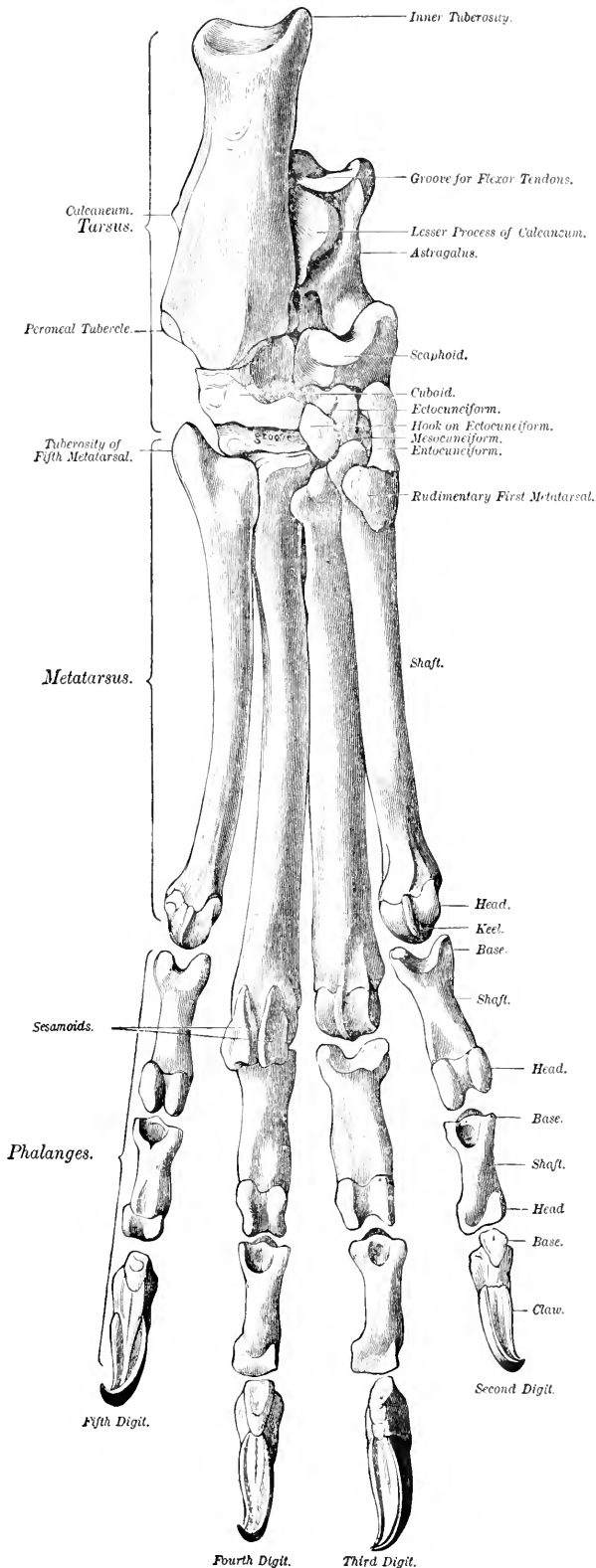
**Muscular Attachments.**—A part of the **extensor brevis digitorum** arises from the dorsal surface, the **adductores minimi digiti** and **indicis** and the **opponens minimi digiti** from the palmar surface, proximal to the groove for the peroneus longus tendon.

**Ossification.**—The cuboid is developed from one centre of ossification.

#### THE METATARSUS.

**General Description.**—The Metatarsus lies between the tarsus and the digits, and forms what corresponds to the instep and part of the sole of the human foot (Fig. 587). It is composed of four long

FIG. 587.



LEFT FOOT, PLANTAR ASPECT

bones and a rudimentary ossicle, called metatarsals, which are placed side by side, united at their proximal ends where they articulate with the tarsal bones, and distally free and diverging to support the digits.

The metatarsus as a whole is a flattened oblong, whereof the middle length is three times as great as the width at the proximal end, and twice as great as the width at the distal end. The outline of its **proximal extremity** is irregular, owing to the different shapes and lengths of the bases of the metatarsal bones. The sides are bowed toward the middle line, the outer or fibular side more strongly than the inner or tibial. The outline of the **distal extremity** is that of a truncated triangle, owing to the fact that the two median metatarsals are longer than the two lateral. The **dorsal aspect** of the metatarsus is gently convex from the proximal to the distal end and strongly convex from side to side; the **plantar surface** is, therefore, correspondingly concave in these directions.

The metatarsus is a fourth longer than the tarsus and a little more than a fourth longer than the middle digit. Its width at the proximal end is about the same as the width of the tarsus; at the distal end it is somewhat wider. It differs from the metacarpus in having but four large constituent bones, which are placed more closely together, and in being about a third longer and slightly wider.

**Nomenclature.**—The word metatarsus was not known to the Greeks nor used by Galen. It was introduced by Laurentius, and is a compound of *meta*, beyond, and *tarsus*. The German for metatarsus is *der Mittelfuss*; the French, *le métatarse*.

#### CHARACTERS COMMON TO ALL METATARSAL BONES.

**General Description.**—The Metatarsals so closely resemble the metacarpals that, except for the difference in size, they can be distinguished from them only by minor characters. They have irregular bases; long, slightly curved shafts, presenting tibial, fibular, and plantar borders, dividing dorsal, tibial, and fibular surfaces, and rounded, keeled heads. The base of each metatarsal is so very similar to the base of the corresponding metacarpal that the description of the latter already given would almost suffice. For greater clearness a few words concerning the bases may be added.

**Nomenclature.**—The metatarsal bones are called *ossa metatarsalia*, and are numbered from the tibial to the fibular side, namely,



from the first metatarsal, or *os metatarsale primum*, to the fifth metatarsal, or *os metatarsale quintum*. In German they are numbered from *der erste* to *der fünfte Mittelfussknochen*; in French, from *le premier* to *le cinquième métatarsien*.

**Articulations.**—By the base: The first metatarsal articulates with the second metatarsal and the entocuneiform; the second, with the first and third metatarsals and the three cuneiforms; the third, with the second and fourth metatarsals and the ectocuneiform; the fourth, with the third and fifth metatarsals and the cuboid; the fifth, with the fourth metatarsal and the cuboid. By the head: Every metatarsal articulates with the proximal phalanx of its respective digit.

**Blood-Supply.**—The nutrient foramen of the second metatarsal is on the fibular border of the shaft, not far from the base; the foramina of the other metatarsals are at the same level, but on the tibial border. The vessels are derived from a common trunk arising from the plantar artery just as it makes its appearance on the sole of the foot, between the second and third metatarsals.

**Ossification.**—The metatarsals arise by two centres of ossification, one for the base and shaft and one for the head.

### THE FIRST METATARSAL BONE.

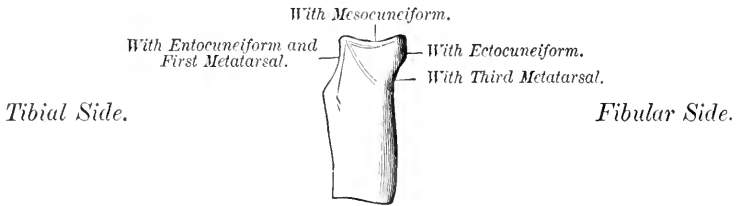
The First Metatarsal (Fig. 587), that of the rudimentary great toe, or hallux, is little more than a bony ossicle applied to the inner and plantar side of the proximal end of the metatarsus. It has a conical shape, although it is subject to much variation in form. On its proximal end is an oval, flat surface for articulation with the entocuneiform. It is firmly united by its roughened fibular side to the tibial side of the end of the second metacarpal. The first metatarsal affords insertion to the tibialis anticus and the peroneus longus, and origin to the first plantar and first dorsal interosseous muscles.

### THE SECOND METATARSAL BONE.

**General Description.**—The base is bent to the fibular side, but there is no oblique arterial furrow on the dorsal surface (Fig. 588).

The tibial surface (Fig. 589) presents along the proximal edge a narrow facet for articulation with the distal part of the fibular surface of the entocuneiform. Below this facet is a deep, roughened, oval depression facing principally to the plantar side, and serving for the

FIG. 588.

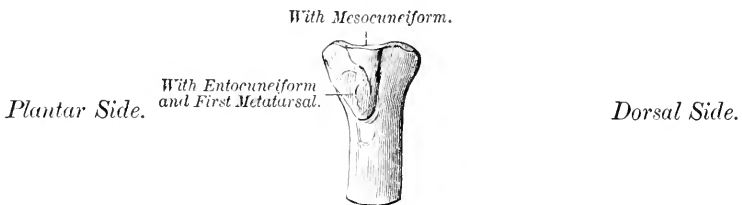
*Proximal End.*

SECOND LEFT METATARSAL, DORSAL SURFACE OF BASE AND PART OF SHAFT.

attachment of the ligament binding the rudimentary first metatarsal to the second.

The plantar angle (Fig. 590), although prominent, is not produced into a hook.

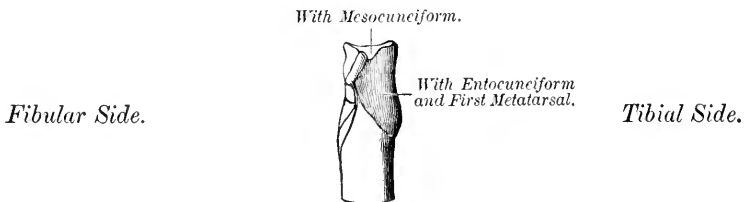
FIG. 589.

*Proximal End.*

SECOND LEFT METATARSAL, TIBIAL SURFACE OF BASE AND PART OF SHAFT.

On the fibular surface (Fig. 591) are two large circular depressions, one dorsal and the other plantar, separated by a longitudinal ridge. The proximal halves of these concavities receive swellings on

FIG. 590.

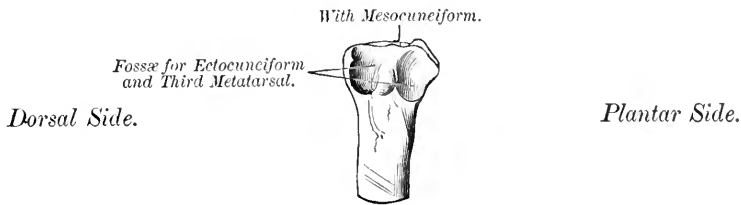
*Proximal End.*

SECOND LEFT METATARSAL, PLANTAR SURFACE OF BASE AND PART OF SHAFT.

the distal end of the tibial surface of the ectocuneiform, and the distal halves articulate with rounded prominences on the tibial side of the

third metatarsal. The ridge between affords attachment for ligaments from the ectocuneiform and the third metatarsal.

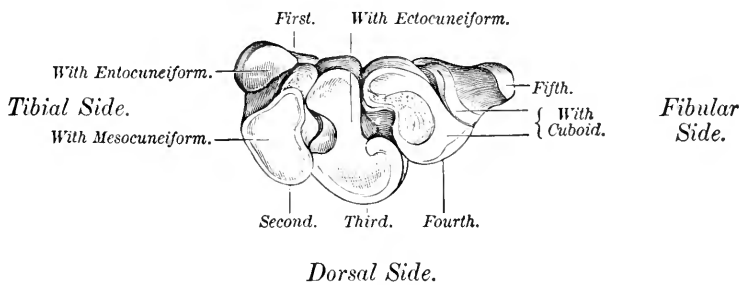
FIG. 591.  
*Proximal End.*



SECOND LEFT METATARSAL, FIBULAR SURFACE OF BASE AND PART OF SHAFT.

The outline of the **proximal surface** (Fig. 592) is usually irregularly crescentic, with the concavity toward the fibular side. It is a smooth articular surface, gently concave transversely, and successively convex, concave, and convex from the plantar to the dorsal end. It articulates with a crescentic facet on the tibial side of the distal surface of the mesocuneiform.

FIG. 592.  
*Plantar Side.*



THE FIVE METATARSAL BONES IN POSITION, PROXIMAL ASPECT OF BASES.

**Determination.**—If the bone be held with the base uppermost and the plantar side toward the student, the base will incline to the side to which the bone belongs.

**Muscular Attachment.**—The first dorsal interosseous is attached to the tibial side of the shaft.

### THE THIRD METATARSAL BONE.

**General Description.**—The base is somewhat different from the base of the third metatarsal. Its **proximal surface** (Fig. 592) is rudely

T-shaped in outline, the cross-bar on the dorsal side, the vertical bar directed toward the plantar and tibial sides. The fibular margin is more completely and more deeply emarginated than is the tibial margin. The surface is almost flat, and articulates with the distal surface of the ectocuneiform.

The dorsal surface (Fig. 593) is quadrate, and lacks the hook on the median side which characterizes the third metacarpal. It is gently convex transversely, and flat or slightly concave from the proximal to the distal end.

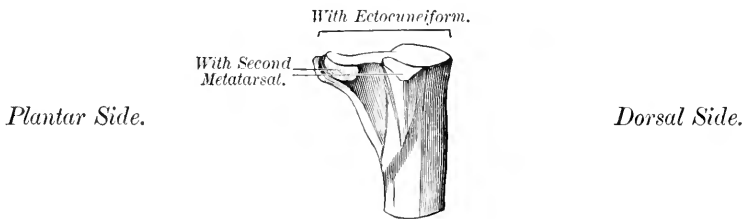
FIG. 593.  
*Proximal End.*



THIRD LEFT METATARSAL, DORSAL SURFACE OF BASE AND  
PART OF SHAFT.

The tibial surface (Fig. 594) has two convex prominences on the proximal border which are separated by a deep groove. They articulate with the lower halves of corresponding depressions on the fibular

FIG. 594.  
*Proximal End.*



THIRD LEFT METATARSAL, TIBIAL SURFACE OF BASE AND  
PART OF SHAFT.

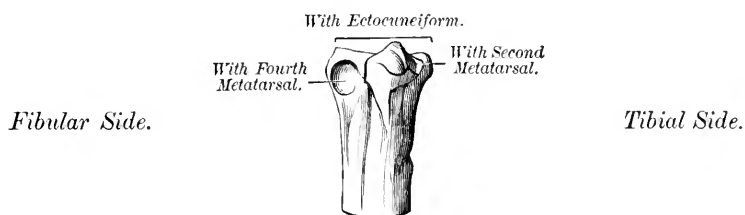
side of the base of the second metatarsal. In the separating groove are inserted strong ligaments from the adjoining bones.

The narrow plantar surface (Fig. 595) is prolonged at the proximal end into a strong, rounded prominence.

The fibular surface (Fig. 596) presents, on the proximal border at the dorsal end, a convex strip for the attachment of a ligament.

This prominence overhangs a deep, rounded concavity, which is adjusted to a swelling on the tibial side of the base of the fourth metatarsal. On the plantar side of the prominence is an oval, deeply concave, articular surface for another prominent articular swelling on the plantar side of the tibial surface of the fourth metatarsal.

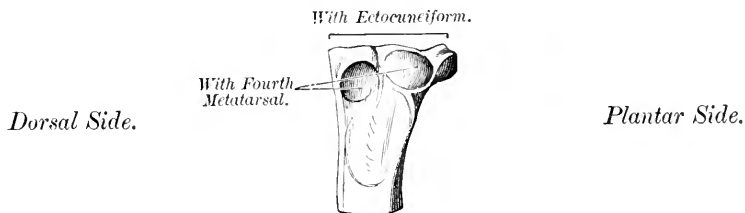
FIG. 595.  
*Proximal End.*



THIRD LEFT METATARSAL, PLANTAR SURFACE OF BASE AND PART OF SHAFT.

**Determination.**—The third metatarsal is distinguished by the T-shaped proximal surface. If it be held with the base uppermost and the plantar surface toward the student, the deep concavity on the fibular surface of the base will be on the side to which the bone belongs.

FIG. 596.  
*Proximal End.*



THIRD LEFT METATARSAL, FIBULAR SURFACE OF BASE AND PART OF SHAFT.

**Muscular Attachments.**—The third metatarsal affords origin, by the proximal end of the plantar aspect, to the second plantar interosseous muscle, and by each side of the shaft to the second and third dorsal interosseous muscles. A part of the extensor brevis digitorum arises from the dorsal aspect of the base.

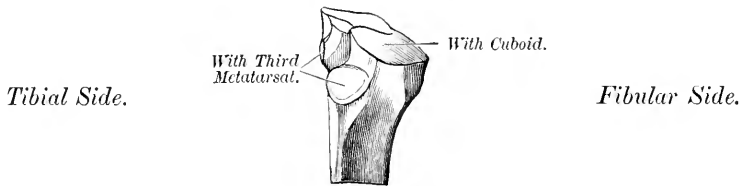
#### THE FOURTH METATARSAL BONE.

**General Description.**—The base of the Fourth Metatarsal is similar to the base of the fourth metacarpal. It differs from the base

of the third metatarsal by its smaller size, and by being so twisted on the long axis of the bone that the dorsal surface faces to the fibular side as well as dorsally, and almost the entire tibial surface appears on the dorsal aspect.

The dorsal surface (Fig. 597) is narrow and directed toward the plantar and fibular sides.

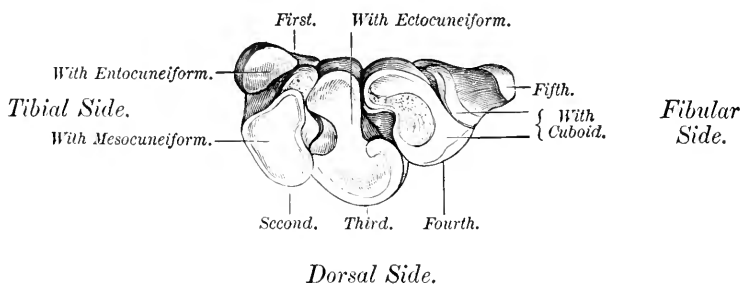
FIG. 597.  
*Proximal End.*



FOURTH LEFT METATARSAL, DORSAL SURFACE OF BASE AND  
PART OF SHAFT.

The proximal surface (Fig. 598) is oblong; its long diameter is directed from the dorsal end to the plantar and tibial sides. The dorsal and plantar margins are faintly arcuate, the fibular margin is straight, with a little projection at the plantar end, and the tibial margin is emarginate at the middle. The surface is slightly convex transversely and alternately gently convex and concave as it slopes

FIG. 598.  
*Plantar Side.*



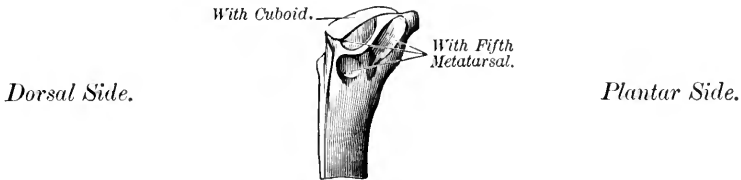
THE FIVE METATARSAL BONES IN POSITION, PROXIMAL  
ASPECT OF BASES.

from the plantar end dorsally to the distal end. It is smooth, except for a small space adjoining the tibial emargination; it articulates with the distal surface of the cuboid.

The fibular surface (Fig. 599) faces to the plantar as well as to the fibular side. It consists of two parts, namely, an articular strip along

the proximal edge (and continued in some specimens for a short distance down the plantar border), and an adjoining but more distal concavity. The articular strip is concave in both directions, and sometimes a groove for a slip from the tendon of the peroneus longus

FIG. 599.  
*Proximal End.*

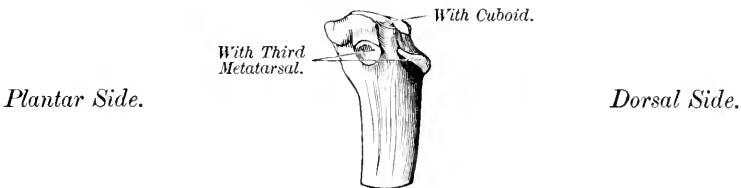


FOURTH LEFT METATARSAL, FIBULAR SURFACE OF BASE AND  
PART OF SHAFT.

muscle divides it into dorsal and plantar halves. It joins the articular facets on the tibial side of the base of the fifth metatarsal; one of these facets also fits into the anterior half of the adjoining concavity, whereof the posterior half is rough and affords attachment to a ligament.

The tibial surface (Fig. 600) is rough and irregular. On the dorsal border, at some distance from the proximal rim, is a projection, bearing a smooth oval surface, which faces to the proximal, tibial, and

FIG. 600.  
*Proximal End.*



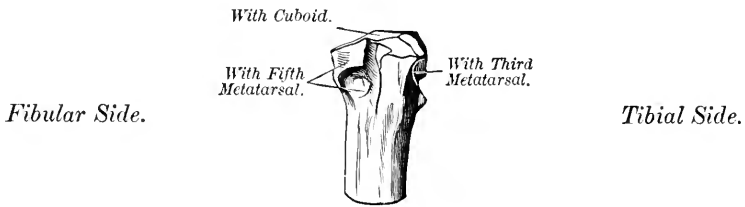
FOURTH LEFT METATARSAL, TIBIAL SURFACE OF BASE AND  
PART OF SHAFT.

dorsal sides and fits into the deep excavation on the fibular side of the base of the third metatarsal. Proximal to this projection is a shallow area which is adjusted to a swelling on the third metatarsal. The entire surface is divided into two by a median groove. On the prominent plantar border, and encroaching also somewhat on the plantar surface, is an oval, slightly concave facet. It faces to the plantar and the tibial side, and articulates with the plantar concavity on the fibular surface of the third metatarsal.

The proximal rim of the concave **plantar surface** (Fig. 601) is swollen for ligamentous attachment.

**Determination.**—The fourth metatarsal is recognized by the tubercle on the tibial side of the base. When the bone is held with the base uppermost and with the plantar side in front, the straight side of the proximal surface is on the side to which the bone belongs.

FIG. 601.

*Proximal End.*

FOURTH LEFT METATARSAL, PLANTAR SURFACE OF BASE AND PART OF SHAFT.

**Muscular Attachments.**—To the fibular side of the base is attached a slip from the tendon of the **peroneus longus**; on the plantar aspect is the area of the origin of the **third plantar interosseous**. The **fourth dorsal interosseous** muscle arises from the fibular side of the shaft.

#### THE FIFTH METATARSAL BONE.

**General Description.**—The Fifth Metatarsal has a prismatic **Base**, which is compressed in an oblique direction from the dorso-tibial side to the fibulo-plantar side. The fibular angle is prolonged into a large, pointed **tuberosity** for ligamentous and muscular attachment.

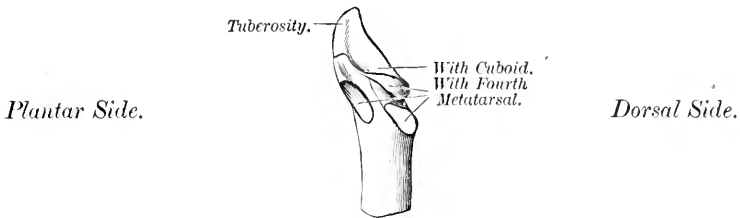
The triangular **proximal surface** (Fig. 598) is continued upon this tuberosity as its tibial surface, which joins the fibular side of the cuboid and forms with it the **peroneal canal**. Distal to the tuberosity is a crescentic articular facet for the distal end of the fibular side of the cuboid.

The **tibial surface** (Fig. 602) lies almost in the same plane as the proximal, facing to the dorsal and tibial sides. It exhibits on its dorsal half a bi-convex articular facet, separated by a median groove from a long facet on the plantar rim. The facets articulate with facets on the fibular side of the fourth metatarsal, and the groove serves for ligamentous attachment.

The **dorsal surface** (Fig. 603) is narrow and pointed above; its



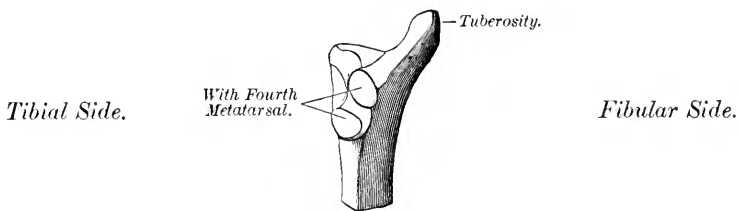
FIG. 602.  
*Proximal End.*



FIFTH LEFT METATARSAL, TIBIAL SURFACE OF BASE AND  
PART OF SHAFT.

tibial border presents a notch which corresponds to the facet on the tibial surface. It is smooth, convex from side to side, and concave toward the proximal point. It faces almost directly to the fibular side of the foot.

FIG. 603.  
*Proximal End.*

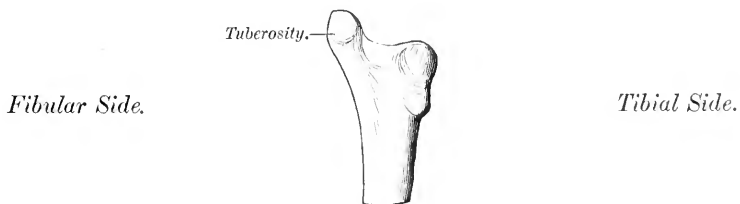


FIFTH LEFT METATARSAL, DORSAL SURFACE OF BASE AND  
PART OF SHAFT.

The plantar surface (Fig. 604) is wide above and narrow below. It has an emarginate proximal border and a produced fibular angle. It is almost flat, or presents a median longitudinal groove. Owing to the prismatic form of the base, there is no true fibular surface.

**Determination.**—The fifth metatarsal may be known as the meta-

FIG. 604.  
*Proximal End.*



FIFTH LEFT METATARSAL, PLANTAR SURFACE OF BASE AND  
PART OF SHAFT.

tarsal with the long proximal tuberosity. When held with the base uppermost and the plantar side toward the student, the tuberosity is on the side to which the bone belongs.

**Muscular Attachments.**—The base of the fifth metatarsal affords insertion to the *peroneus brevis* and the *abductor ossis metatarsi*, and origin to the *extensor brevis digitorum* and the fourth plantar interosseous. The *opponens minimi digiti* is inserted along the tibial side of the shaft, on the plantar aspect.

### THE PHALANGES.

Every one of the four digits, or toes, which compose the distal part of the foot consists of three phalanges, constructed on the same plan as the phalanges of the fingers and closely resembling them.

### THE PROXIMAL PHALANGES.

Every Proximal Phalanx has its proximal end or base excavated to articulate with the rounded head of its metatarsal, and the distal end or head formed of a trochlea or pulley, which is convex from the dorsal to the plantar side, concave transversely, and articulates with the proximal end of the middle phalanx.

The third proximal phalanx is very little larger than the fourth, and both are longer and stouter than the second, which in turn is longer and stouter than the fifth. The third and fourth are bilaterally symmetrical, but the second and especially the fifth have the median side more strongly concave than the opposite side.

The proximal phalanges of the toes are shorter and stouter in proportion to the length of the foot than the corresponding phalanges of the fingers are in proportion to the length of the hand.

### THE MIDDLE PHALANGES.

The Middle Phalanx of a toe is recognized by its concave proximal surface, with its overhanging dorsal projection, by the concavity on the fibular side of the shaft, and by the transversely cylindrical head. The middle phalanges decrease in size from the third to the fifth in the same order as the metatarsals. As compared with the middle phalanges of the fingers, they are shorter and stouter.

### THE DISTAL PHALANGES.

The Distal Phalanx bears the large, triangular, curved claw-plate on its dorsal surface. It is in all respects like the distal phalanx of

the finger, except that in many cases the collar-like sheath of the claw is narrower and the claw-plate and claw appear less strongly curved.

**Muscular Attachments.**—The dorsal and plantar interosseous muscles are attached to the sesamoids and to the plantar side of the base of every proximal phalanx; in addition, the adductor indicis is inserted on the fibular side of the base of the proximal phalanx of the second digit, and the adductor minimi digiti and the abductor minimi digiti on the tibial and fibular sides respectively of the base of the proximal phalanx of the fifth digit. The common tendons of the *extensores brevis* and *longus digitorum* and of the *lumbricales* are inserted on the dorsal side of the base of the middle and distal phalanx, the *flexor longus digitorum* on the base of the distal phalanx, and the *flexor brevis digitorum* on the base of the middle phalanx.

#### MUSCULAR ATTACHMENTS ON THE FOOT.

##### MUSCLES ATTACHED TO THE TARSUS.

On the Astragalus, part of the origin of the *extensor brevis digitorum*.

On the Calcaneum, part of the origin of the *extensor brevis*; the origin of the *abductor ossis metatarsi minimi digiti*, the *abductor minimi digiti*, and the plantar head of the *flexor longus digitorum*; the insertion of the *gastrocnemius* and *soleus*.

On the Entocuneiform, the insertion of the *tibialis posticus*.

On the Ectocuneiform and Cuboid, part of the origin of the *extensor brevis digitorum*.

From the plantar ligaments at the distal end of the tarsus, the origins of the *adductores indicis* and *minimi digiti*, the *opponens minimi digiti*, the proximal ends of the plantar interosseous muscles.

##### MUSCLES ATTACHED TO THE METATARSUS AND PHALANGES.

On the First Metatarsal, the insertion of the *tibialis anticus* and the *peroneus longus* and part of the origin of the first plantar interosseous muscle.

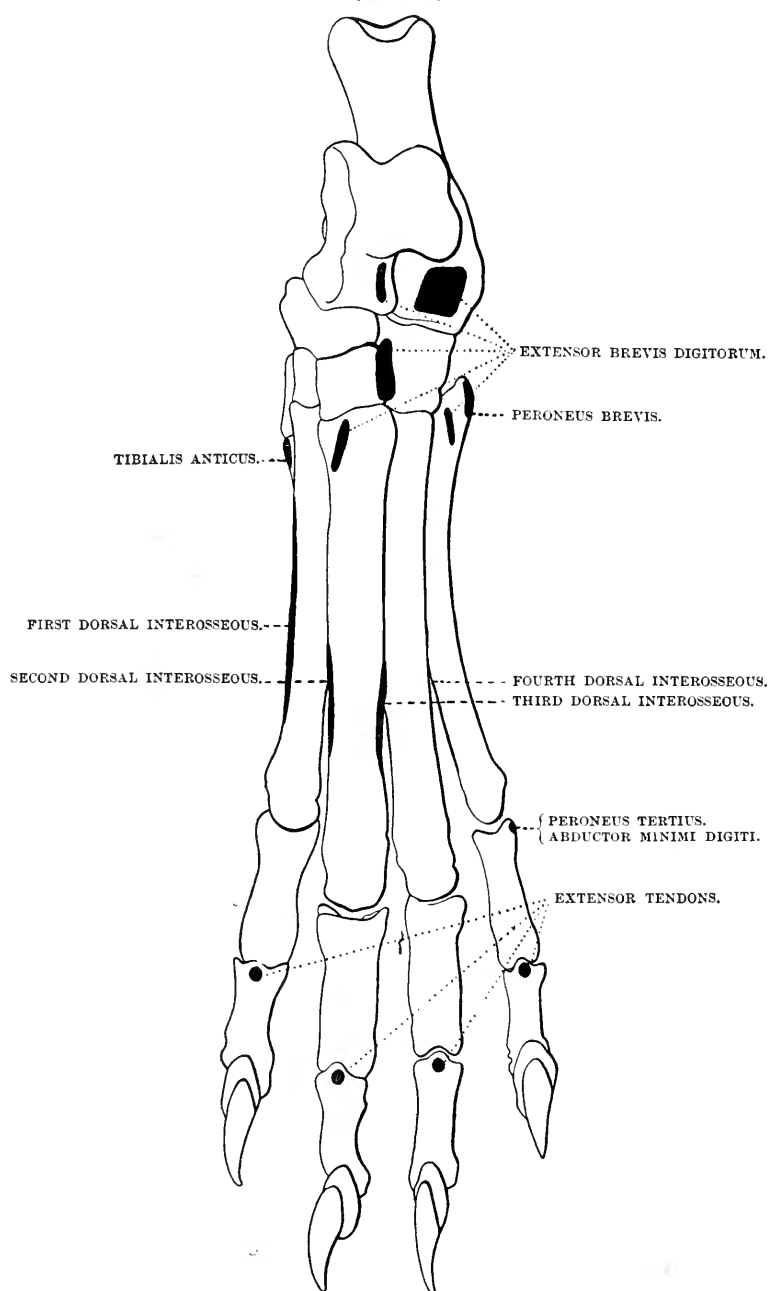
On the Second Metatarsal, the origin of the first plantar and first dorsal interosseous muscles.

On the Second Digit:

- (a) Proximal phalanx, the insertion of the first dorsal and first plantar interosseous muscles and of the adductor indicis.

- (b) Middle phalanx, the insertion of the *flexor brevis digitorum* and the common tendon of the *extensores longus* and *brevis digitorum*.

FIG. 605.



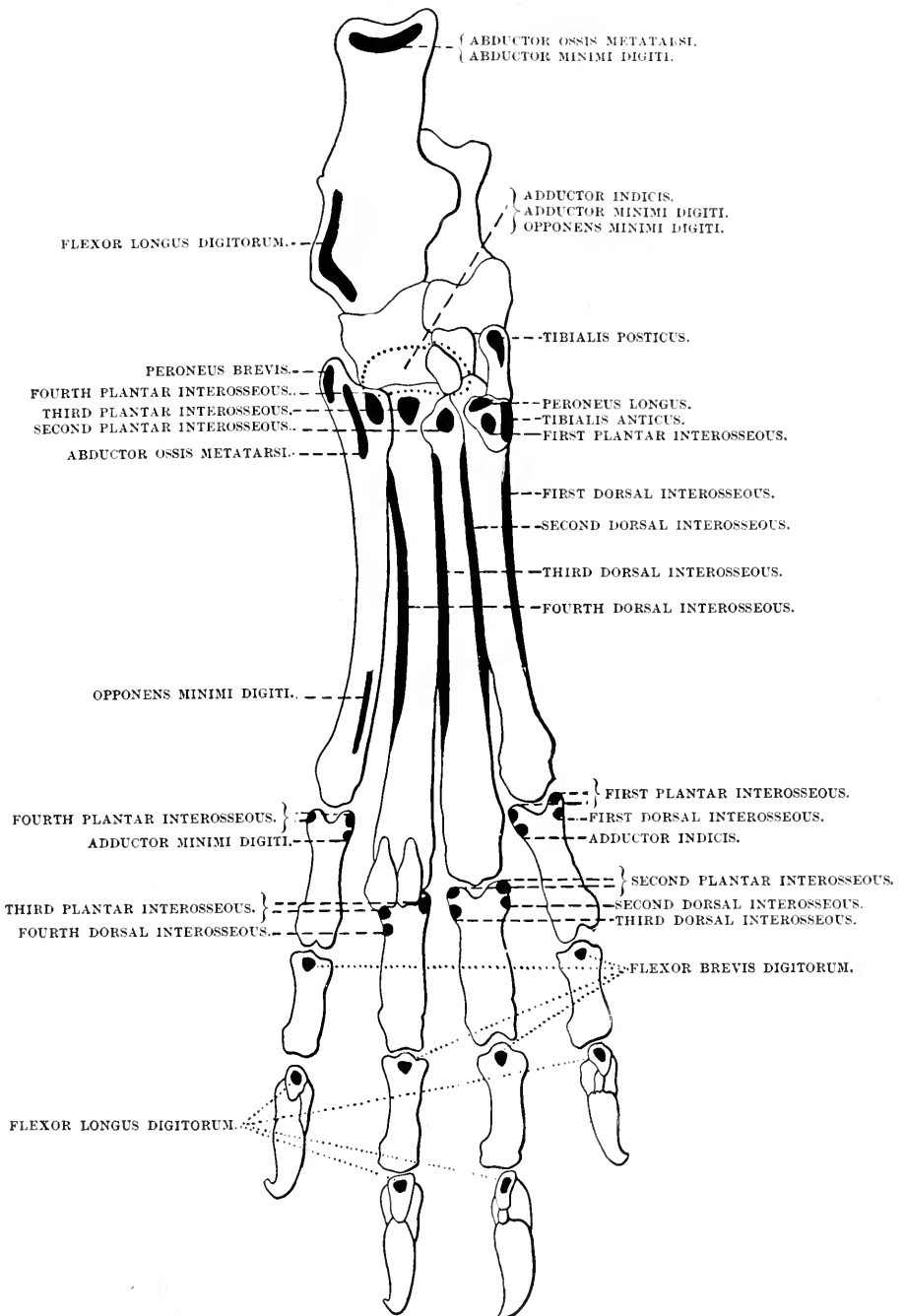
MUSCLES ATTACHED TO THE FOOT. DORSAL ASPECT.

- (c) Distal phalanx, the insertion of the *flexor longus digitorum*.

On the Third Metatarsal, part of the origin of the *extensor brevis*

digitorum, the origin of the second plantar and the second and third dorsal interosseous muscles.

FIG. 606.



MUSCLES ATTACHED TO THE FOOT. PLANTAR ASPECT.

On the Third Digit:

- (a) Proximal phalanx, the insertion of the second plantar and the second and third dorsal interosseous muscles.

(*b, c*) Middle and Distal phalanges as in the second digit.

On the Fourth Metatarsal, the origin of the third plantar and fourth dorsal interosseous muscles.

On the Fourth Digit :

(*a*) Proximal phalanx, the insertion of the third plantar and fourth dorsal interosseous muscles.

(*b, c*) Middle and Distal phalanges as in the second digit.

On the Fifth Metatarsal, the insertion of the abductor ossis metatarsi minimi digiti, the peroneus brevis, the opponens minimi digiti, and the origin of the fourth plantar interosseous muscle.

On the Fifth Digit :

(*a*) Proximal phalanx, the insertion of the fourth plantar interosseous muscle, the adductor minimi digiti, the abductor minimi digiti, and the peroneus tertius.

(*b, c*) Middle phalanx and Distal phalanges as in the fourth digit.

The tendons of the lumbricales join the tibial side of the extensor tendons of the third, fourth, and fifth digits.

#### VARIATIONS IN THE FOOT.

Polydactylism affecting the foot of the cat appears to be not uncommon, although I have not been fortunate enough to meet with examples of it.

The following classification, as well as the figures, are taken from Bateson.<sup>1</sup>

In all cases the abnormality is confined to the tibial side of the foot; the three outer toes are always normal. The tarsal bones may be normal, but more commonly on the tibial side of the mesocuneiform there are two cuneiforms, entirely separate or more or less joined together and with the mesocuneiform. In one specimen the scaphoid was divided, and each half articulated with two cuneiforms.

The examples of polydactylism in the cat's foot may be arranged in three groups :

1. The foot has five toes; the first toe, on the tibial side, has three phalanges, and, inasmuch as the terminal phalanx can be retracted to the tibial side of the middle phalanx, is formed like a toe of the opposite foot. The second toe also has three phalanges, but the terminal

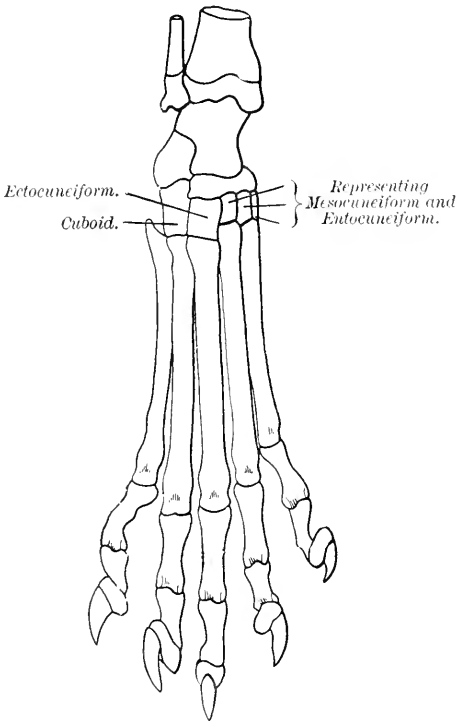
<sup>1</sup> Materials for the Study of Variation, p. 314.

phalanx cannot be retracted, and, although there are evidences of the toe being formed like a toe of the opposite foot, it must be classed as "indifferent" (Fig. 607).

2. The foot has six toes. The first toe on the tibial side has two phalanges, and in respect of its terminal phalanx is "indifferent;" the second and third toes each have three phalanges, and are formed like toes of the opposite foot (Fig. 608).

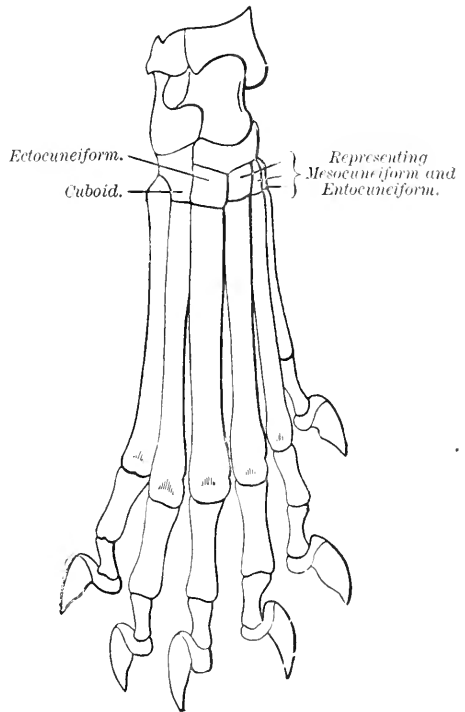
In one specimen, which may be regarded as a modification of this type, the first toe on the tibial side had two phalanges and was indifferent; the second toe was very thick, bore a partially double nail, and was indifferent; and the third toe was only slightly formed, like a toe of the opposite foot.

FIG. 607.



ABNORMAL RIGHT FOOT.

FIG. 608.



RIGHT FOOT WITH SUPERNUMERARY DIGITS.

3. The foot has six toes, all with three phalanges.

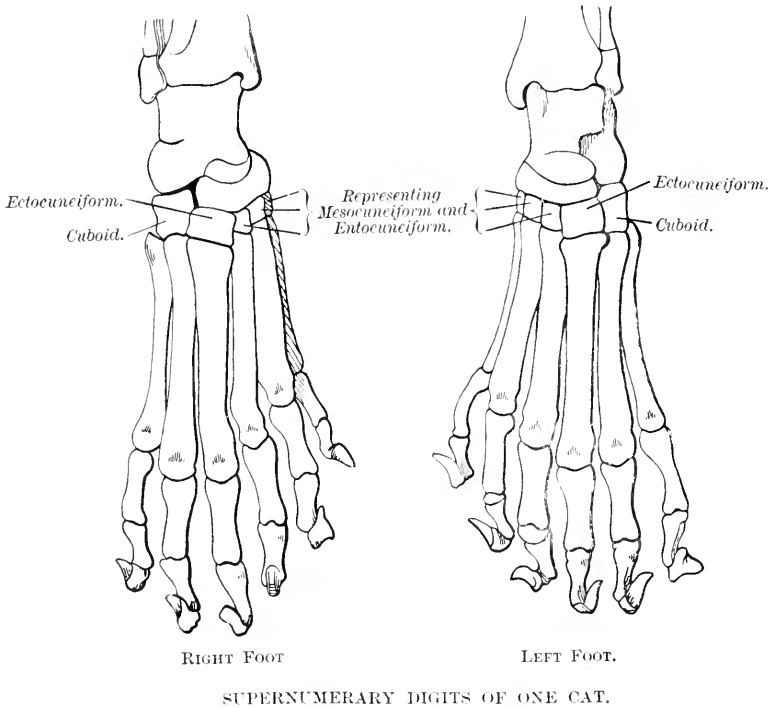
1. The inner three toes are formed as toes of the opposite foot (Fig. 609, left foot). In one specimen recorded the two tibial digits were completely united in their metatarsals and first phalanges.

2. The first toe on the tibial side is indifferent; the second toe is

formed like a toe of the opposite foot; and the third toe is either indifferent or almost normal (Fig. 609, right foot). A modification of this type has been described in which all four outer digits were normal, but the metatarsals of the two inner digits were coalesced at their proximal and distal ends, and supported three amorphous phalanges with three claws, two large and one rudimentary.

This type of polydactylous foot appears most frequently.

FIG. 609.



### HUMAN FOOT.

The human foot (Figs. 610, 611) differs from the cat's foot principally by its relatively shorter and broader form, and by the possession of a very large first digit or great toe, which consists of a metatarsal bone and two phalanges. The other changes in the foot are the result of the weight it sustains by being placed flat on the ground.

The tarsus is relatively long. The seven tarsal bones closely resemble in shape and in the areas of articulation the tarsal bones of the cat. The entocuneiform, which supports the great toe, is relatively much larger, and the ectocuneiform is relatively much smaller.

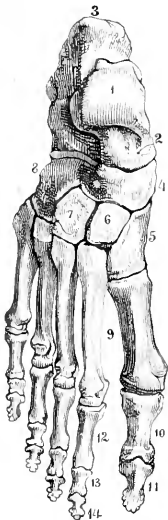
The astragalus is cuboidal; its neck is not so well marked, and



there is a grooved area for the flexor longus hallucis tendon on the superior surface behind the trochlea. The trochlea lacks the deep longitudinal groove and is flatter. On the outer surface is the articular surface for the fibula, which is larger than the articular surface for the tibia on the inner surface. The lower surface resembles that surface on the astragalus of the cat; it presents two facets for the calcaneum. The head articulates also with the calcaneum, but principally with the scaphoid.

The **calcaneum** is relatively shorter than in the cat; the superior surface, behind the articular surface for the astragalus, is broader. The posterior surface is larger and more swollen on the plantar side to form definite internal and external tubercles. The lesser process,

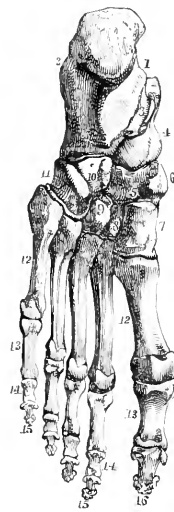
FIG. 610.



RIGHT FOOT, DORSAL SURFACE.

1, body of the astragalus; 2, its head; 3, calcaneum; 4, scaphoid bone; 5, 6, 7, ento-, meso-, and ectocuneiform bones; 8, cuboid bone; 9, metatarsal bones; 10, 11, phalanges of the great toe; 12, 13, 14, phalanges of the other toes.

FIG. 611.



SOLE OF THE LEFT FOOT.

1, concavity of the calcaneum; 2, outer face of the same; 3, groove for the tendon of the flexor longus hallucis; 4, head of the astragalus; 5, scaphoid bone; 6, its tuberosity; 7, 8, 9, ento-, meso-, and ectocuneiform bones; 10, cuboid bone; 11, its groove for the tendon of the peroneus longus muscle; 12, metatarsal bones; 13, first row of phalanges; 14, second row; 15, third row; 16, last phalanx of the great toe.

or sustentaculum, on the inner surface is well developed, as is the concavity beneath for the flexor tendons. The outer surface is grooved for the peroneal tendons. The anterior surface presents a triangular slightly concave facet for the cuboid. The articular facets on the upper surface are shorter and more angular than in the cat; of the two, the outer is much the larger.

The **scaphoid** can be easily recognized by its characteristic form. Its concave proximal surface articulates with the astragalus; its convex distal surface, by the three triangular facets, joins the three cuneiform bones. In some specimens the outer surface articulates with the cuboid.

The **entocuneiform** is the largest of the three. In form it is almost quadrate, but greatly flattened. The proximal surface articulates with the scaphoid, the distal surface with the first metatarsal, and the outer surface with the mesocuneiform and the second metatarsal. Its plantar surface presents a blunt tuberosity.

The **mesocuneiform** is somewhat prismatic, the narrow side on the sole of the foot. The bone articulates with the scaphoid, the second metatarsal, and the other two cuneiforms.

The **ectocuneiform** is relatively much smaller than in the cat, and lacks the long plantar hook. By its four surfaces it articulates with the scaphoid; the cuboid and the fourth metatarsal; the mesocuneiform and the second metatarsal; and the third metatarsal.

The **cuboid** articulates by its proximal surface with the calcaneum, by its inner surface with the scaphoid and ectocuneiform but not with the fourth metatarsal, and by its distal surface with the fourth and fifth metatarsals.

The **first metatarsal** is shorter and more strongly developed than the others, which are comparatively slender and decrease in size from within outward. Their bases are less complex than in the cat. Sesamoid bones are developed only on the great toe.

The **phalanges** of the foot resemble the phalanges of the hand, but, with the exception of those of the great toe, they are less developed. The shafts of the proximal phalanges are very narrow; the shafts of the middle and distal phalanges are broad, and are distinguishable only as slight transverse constrictions of the bone.

#### THE NUTRIENT CANAL AND THE GROWTH OF BONES.

On page 38, in referring briefly to the relative growth of the parts of bones, mention was made of the fact that the shaft of a long bone unites first with that epiphyseal end toward which the canal for the nutrient artery is directed. The student must not suppose, however, that this fact can explain all the problems which arise in the study of relative growth; other facts must be settled before the subject can be

properly approached. Some of these facts concerning the growth of the long bones of the cat, and such as can be fixed without the aid of the microscope, I have given in the following table :

	Nutrient foramen nearer the	Nutrient canal directed toward the	Ossification appears first in the	Shaft unites first with the
Humerus . . . . .	lower end	lower end	upper end	lower end
Ulna . . . . .	upper end	upper end	lower end	upper end
Radius . . . . .	upper end	upper end	lower end	upper end
Femur . . . . .	upper end	upper end	lower end	upper end
Tibia . . . . .	upper end	lower end	upper end	lower end
Fibula . . . . .	upper end	lower end	lower end	lower end

VARIATIONS IN THE SIZE OF THE APPENDICULAR SKELETON.

For purposes of comparison I have given in the following table the relative lengths, in millimetres, of the principal bones of the appendicular skeleton, in ten specimens :

	Scapula.	Humerus.	Ulna.	Radius.	Innominate.	Femur.	Tibia.	Fibula.
Male . . . . .	76	99	114	97	82	109	115	104
Male . . . . .	71	92	107	90	76	101	107	99
Male . . . . .	75	101	111	94	83	109	112	103
Male . . . . .	78	104	115	98	85	112	117	109
Male . . . . .	75	100	113	96	82	108	116	108
Male . . . . .	69	97	105	93	77	106	113	106
Female . . . . .	64	87	100	85	73	92	98	91
Female . . . . .	64	85	97	81	72	94	97	90
Female . . . . .	67	92	101	86	75	100	104	97
Female . . . . .	69	91	101	87	77	96	105	97



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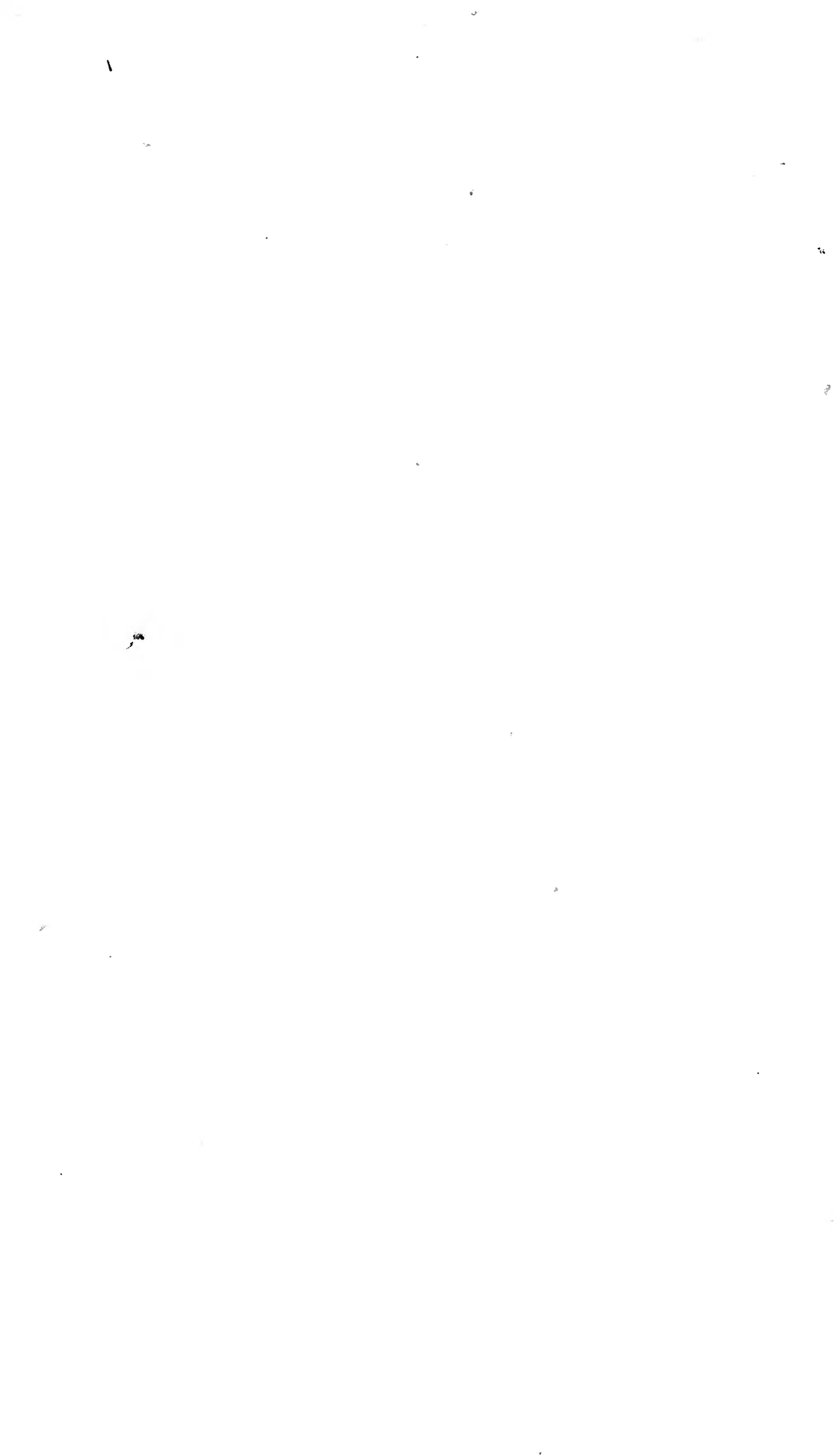
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